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A Descriptive Study of Certain Tuna-like Fishes

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FOREWORD

This bulletin contains technical descriptions of a number of species of tuna-like fishes and an evaluation of their relationships to each other and to the tunas proper.

The classification of the tunas and the tuna-like fishes has long been a controversial topic. The general similarity in form and fin structure suggests a close relationship between the tunas and the large remaining group of mackerel-like fishes. Hence, the tunas, with the latter, were originally included in a single family, the *Scombridae*. More detailed study of the tunas proper showed, however, that they differ fundamentally in a number of ways, and this discovery led to the separation of the tunas into a family distinct from the mackerels. While this separation was endorsed by those scientists who had particularly investigated the group the separation was not universally accepted, and the classification of the tunas and mackerel-like fishes is still the subject of considerable discussion. Divergent opinions are based for the most part on the relative importance assigned to particular characters. The true, or at least most probable relationship can be determined only by a thorough and comparative examination of the anatomical organization of each species, and by a critical evaluation of the total findings. This is generally recognized, but the scope of the problem and its academic nature prevented the Department of Fish and Game from devoting the necessary time to such a study in the past.

This problem, however, assumed practical and immediate importance when standards of identity were under discussion for the tuna industry. The California—and the national—industry was abruptly faced with the problem of defining the term "tuna." What species could, or should, be included with the tunas, and to what species should the term be restricted? The answers were to a certain extent a matter of opinion, and as such, could be controverted in a public hearing. To avoid this controversy and to provide an acceptable definition the California industry requested the department to investigate the problem and provide a sound basis for the definition of the term "tuna." In particular, the industry wanted to know what factual basis existed for excluding from the pack of tuna such species as the bonito, the black skipjack and the frigate mackerel. They requested a definition of the term "tuna" which would eliminate as far as possible arbitrary decisions as to the inclusion or exclusion of a particular species. They wanted valid biological criteria which would impartially decide what species could or could not be packed as tuna.

The answers to these questions could be found only in accurate and adequate comparative descriptions of the several species involved. Such descriptions were not available. Some species had been carefully investigated but the majority had been described only superficially, and such partial descriptions did not always agree. Hence, in order to answer the questions of the industry it was necessary to reinvestigate some of these contradictory statements and to supply detailed descriptions of

certain California species which had not been sufficiently studied. Only upon this basis of fact could the relationship of the several species be critically evaluated. The present bulletin records these findings and evaluates the results.

The selection of a definition of the term "tuna" is not the function of this report. That is the responsibility of the group entrusted with the creation of tuna standards. In this report the Department of Fish and Game is supplying the facts upon which a sound definition can be based. The complete descriptions and findings are published because of their permanent value to fisheries classification, over and above their immediate utility.

As a result of this study it appears that two and only two alternative definitions of the term "tuna" are biologically warranted. The term can be restricted to the tunas proper (family *Thunnidae*), including the California bluefin, the albacore, the yellowfin and the bigeye tuna; or it can be broadened to include, in addition, all members of the skipjack family *(Katsuwonidae)*, including the skipjack, the black skipjack and the frigate mackerel. Either alternative offers a precise definition based on sound anatomical criteria which can be universally and unequivocally recognized. No other alternative is biologically compatible.

ACKNOWLEDGMENTS

In this study I have imposed upon the generosity of numerous individuals. The aberrant specimens of *Euthynnus lineatus* and the specimens of *Auxis* were collected by Mr. H. B. Clemens, while other members of the staff supplied much of the remaining material. To all who so aided my sincere thanks are extended.

In this publication the dissectional notes and observations made upon *E. yaito* by Messrs. E. K. Holmberg and E. C. Greenhood were used. While personally responsible for all statements made, I gratefully acknowledge the use of this material which has served to check my own findings.

To Mr. J. W. Schott, of this staff, belongs the credit for the photographic reproductions of all skeletal elements. I am indebted to him, both for his proffered help and for the skillful accomplishment of a difficult task.

This report is in reality the work of four individuals. As the accredited author of this article, I humbly and gratefully acknowledge the help of Mrs. C. J. Laing, Mrs. H. Freshour and Mr. S. Imamura. All have patiently taken and transcribed the dissectional notes, tabulated and organized the data, prepared manuscripts and drawings and supplied the stimulus of congenial and efficient cooperative work which has resulted in this completed job. In addition, Mr. Imamura has assisted with the routine examination of all the skeletal material. To each of them a full share of the credit belongs. To each I convey my sincere and grateful appreciation.

December, 1953 H. C. Godsil

INTRODUCTION

This project was undertaken in response to an inquiry concerning the relationship of certain species to the tunas. While the original intent was merely to supply a sound biological basis for a definition of the term "tuna", the ultimate scope of the work and the content of this report covers a relatively complete description of the numerous species investigated. Because the work was intermittent, the frequent interruptions and the elapsed time covered by this study have impaired the assimilation of the voluminous results, and interpretive errors have undoubtedly crept in. To overcome this handicap and minimize errors, the description of each species was checked in a final dissection of a specimen of that species, and the written description compared with the findings in that specimen. The evaluation of relationships is based on the specific descriptions rather than upon a current and simultaneous comparison of specimens.

The terms used, and the methods of measuring, counting or enumerating, in the descriptive portion of this report are precisely those defined originally by Godsil and Byers (1944), and reproduced by Godsil and Holmberg (1950). As in those publications, no distinction is made between spines and soft rays of the several fins, and all are included under the heading "rays". Right and left invariably refer to the right and left side of the fish.

A consistent effort has been made throughout to eliminate loose, relative terms. Where possible all distances have been expressed, approximately, in inches or millimeters, and the size of the specimen under discussion has been given for orientation. Where this has been omitted, it is to be inferred that such distances refer to the fish of the particular sample under investigation.

In the description of certain organs, particularly the circulatory and excretory systems, the description follows the routine dissection and not the logical course of the vessels. This procedure resulted inevitably from beginning the dissection (and the description) from a known or obvious point, and working from this to the unknown. Thus with the ureters it is impossible to locate the fine proximal end of each branch, so that the dissection naturally started at the point of injection into the large terminal trunk. Similarly with the cutaneous system the dissection—and the description—goes from the gross to the minute, regardless of the direction of flow of blood.

At the expense of excessive duplication, a complete description of each species is given, followed by a summary of differences. This was purposely done because so much specific detail is lost where a summarized generic description condenses the findings. Experience with the literature dictated this policy.

In regard to nomenclature, the classification proposed by Kishinouye (1923) has been followed throughout. While the present writer does not fully concur in all of Kishinouye's conclusions, his classification accords best with the facts presented in this and my earlier reports.

For those species not described or named by Kishinouye, the currently accepted names have been used uncritically. The several genera discussed in this report fall within the following groups of Kishinouye.

ORDER: Plecostei
- Family: Thunnidae
  - Genus: Thunnus
  - Neothunnus
  - Parathunnus
- Family: Katsuwonidae
  - Genus: Katsuwonus
  - Euthynnus
  - Auxis

ORDER: Teleostei
- Family: Scombridae
  - Genus: Pneumatophorus
- Family: Cybiidae
  - Genus: Sarda
  - Acanthocybium

In the ensuing descriptions and discussion all references to familial and generic characters must be construed to apply only to those forms with which the writer is personally acquainted. Lacking a comprehensive knowledge of the comparative anatomy of fishes in general and of their osteology in particular, and lacking a similar knowledge of the systematic literature, it would be presumptive to extrapolate the conclusions beyond the known facts.

In order to have a factual basis upon which to evaluate relationships, the present report includes a description of two species of *Sarda* and of the Pacific mackerel, *Pneumatophorus diego,* representing, respectively, Kishinouye's families Cybiidae and Scombridae. While this admittedly affords an insufficient foundation upon which to build a solid structure of classification, it suffices to appraise the validity of Kishinouye's order Plecostei.

The writer's interest lies primarily in a separation of the valid species of the Thunnidae and Katsuwonidae and a description of each that will enable a positive identification of any individual. It is his contention that if a specimen cannot be unequivocably assigned by any worker to a given species, then the definition of that species is at fault. The creation of questionable specific and subspecific groups into which an individual must be arbitrarily placed in disregard of other characters is disconcerting and creates the confusion to which every worker in this field alludes. The confusion is in the literature and not in nature. Thus *Euthynnus lineatus* and *E. yaito* are classified by Fraser-Brunner (1949) as subspecies of *E. affinis*, whereas *E. alletteratus* is accorded specific rank. In reality *lineatus* differs anatomically as much from the one as from the other, and has, in fact, a different vertebral structure and a different vertebral count. Similarly the writer is critical of such nugatory specific separations as proposed e.g. by Ginsburg (1953). Discussions of the latter type in particular will explain the emphasis in this report upon positive diagnostic characters. It is hoped that the following descriptions will supply a constructive addition to the knowledge of the group.

PACIFIC MACKEREL (*Pneumatophorus diego*)

This description is based upon the complete dissection of three specimens, supplemented by the examination of individual characters and organ systems in innumerable other specimens, all of which were taken in Southern California, and mostly from Catalina and San Clemente Islands. As fresh material was readily available and as the work was done sporadically, no attempt was made to follow the relatively rigid routine outlined for the tunas. The limited number of resulting counts and measurements is supplemented by a comparable series made by J. E. Fitch upon 39 additional specimens from the same area.

EXTERNAL CHARACTERS

This species can be readily recognized by the separated dorsal fins, the five dorsal and five anal finlets, by the first free spine of the anal fin and by the innumerable short, irregular, wavy black bars on the dorsal half of the body.

FIGURE 1. Pacific mackerel (*Pneumatophorus diego*)

The markings are confined to the dorsal half of the body. They consist of numerous short more or less vertical wavy black bars with irregular black spots between. The markings are superimposed upon a background which is either blue or green. The color is variable and there are as many with the blue background as with the green. The belly is silvery without any superimposed markings. In occasional specimens extremely faint small dusky spots appear in fresh material, but such markings fade rapidly and are rarely apparent in preserved specimens. The pattern of such markings resembles that prevalent in *Pneumatophorus* from the Revilla Gigedo Islands. The body is completely covered with small ctenoid scales.

The lateral line is practically straight. From above the pectoral insertion it slopes slightly downward, and there is below the insertion of the second dorsal fin a slight downward jog. Beneath the base of this fin the lateral line continues its downward slope but levels off beneath, approximately, the first dorsal finlet. There may be slight undulations in the course of the line but these are minor and variable.

There is no caudal keel such as is found in the tunas; however, there are two approximately parallel ridges, or pseudofins (Herald, 1951), one on either side of the median line at the base of the caudal fin.

The posterior margin of the operculum is either straight or slightly convex posteriorly. This outline is nearly vertical to the axis of the body. The preoperculum is characteristic. Its posterior margin approximates a straight line but this line slopes distinctly posteriorly from dorsal to ventral. The posteroventral angle is obtusely rounded. Radiating from the posterior margin of the eye are three or four lines. The eye is covered anteriorly and posteriorly by a partial adipose membrane leaving the pupil itself exposed. The maxillary is entirely concealed (when the jaws are closed, or nearly so) by the preorbital. The maxillary is shorter than the latter and terminates approximately on the vertical through the anterior margin of the eye. In this respect it differs from the bonito and all members of the Plecostei. Vomerine teeth are present and can be felt in two small patches at the anterior end of this bone. The tongue terminates in an anterior apex formed of cartilage and attached to the glossohyal. There are no lateral dorsal ridges such as are found in the tunas and skipjacks. The interpelvic process is single and minute. It is a mere median projection of the membrane connecting the two ventral fins.

The pectoral fin is inserted at a considerable distance anterior to the first dorsal insertion. The pectoral fin is short, reaching approximately to the fifth dorsal spine and is generally rounded in expanded outline. The first dorsal fin is high and roughly triangular. The height is approximately equal to the length of the base. There are nine to eleven rays in this fin. Of these, the second is the longest. The first dorsal is separated from the second dorsal fin by a distance approximately equal to the length of the first dorsal base. There are two spines and usually 11 soft rays in the second dorsal fin. There are generally five dorsal finlets and five anal finlets. The anal fin is preceded by a free short spine. Including this, there are two spines and usually 11 soft rays in this fin. The ventral fins are inserted slightly anterior to the vertical through the first dorsal insertion.

The gill rakers are long and numerous. They are developed on the first arch only. On this arch there is a raker at the angle with a basal process extending both dorsally and ventrally. The raker count is 13 (11-14) + 1 + 27 (26-29). On the anterior or median edge of each raker there is a continuous double row of villiform teeth or spines. These two rows are formed by dual teeth arising from a common base and diverging at a small angle (roughly 10°). On the second and subsequent arches there is on each a complete series of rudimentary rakers. These (and the posterior rakers or gill teeth) are profusely supplied with similar villiform teeth. Gill teeth or posterior rakers are present on all arches but are most developed on the first. On this arch the count was 8 (7-9) + 23 (22-25). Each gill tooth is similarly supplied with a double row of villus teeth on its mesial edge.

The measurements made upon a single large specimen are listed in Table 1, which shows also the range in proportions encountered in the 39 specimens measured by Fitch. Tables 2 and 3 show the resulting meristic counts made upon these 40 specimens.

TABLE 1

Pacific Mackerel: The Measurements, in Millimeters, Made Upon a Single Large Specimen, and the Range in Ratios Derived From Comparable Measurements Made by J. E. Fitch Upon 39 Additional Specimens

Measurements		Ratios	Range in ratios
Body length	452.0		
Head length	119.5	B.L. ÷ H.L.	3.53– 3.95
1st dorsal insertion	155.0	B.L. ÷ 1st dorsal	2.78– 3.02
2d dorsal insertion	283.0	B.L. ÷ 2d dorsal	1.54– 1.63
Anal insertion	301.5	B.L. ÷ Anal	1.42– 1.60
Ventral insertion	147.0	B.L. ÷ Ventral	2.98– 3.27
Greatest body depth	92.0	B.L. ÷ Body depth	4.21– 5.57
Greatest body width	72.5	B.L. ÷ Body width	5.67– 8.49
Length of 2d dorsal base	45.2	B.L. ÷ 2d dorsal base	8.21–10.56
Length of anal base	35.6	B.L. ÷ Anal base	10.47–13.31
Pectoral length	49.5	B.L. ÷ Lg. pectoral	8.19–10.05
Height of 1st dorsal	55.0	B.L. ÷ Ht. of 1st dorsal	7.18– 9.77
Diameter of iris	21.6	H.L. ÷ Iris	4.59– 5.53
Maxillary length	44.7	H.L. ÷ Maxillary	2.43– 2.72

TABLE 2

Pacific Mackerel: Meristic Counts Made Upon 40 Specimens—No Distinction Is Made in This Work Between Soft Rays and Spines

First dorsal rays		Second dorsal rays		Dorsal finlets		Anal rays		Anal finlets	
Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency
9	24	12	2	4	1	13	39	4	1
10	12	13	36	5	39	14	1	5	39
11	4	14	1						
		15	1						
Total	40	Total	40	Total	40	Total	40	Total	40

TABLE 3

Pacific Mackerel: The Count of Gill Rakers and Gill Teeth in 40 Specimens

Gill rakers								Gill teeth					
Upper		Angle		Lower		Total		Upper		Lower		Total	
No.	Frequency	No.	Frequency	No.	Frequency	No.	Frequency	No.	Frequency	No.	Frequency	No.	Frequency
11	6	1	40	26	4	38	3	7	14	22	8	29	3
12	14			27	17	39	3	8	22	23	25	30	16
13	17			28	16	40	7	9	4	24	6	31	12
14	3			29	3	41	15			25	1	32	6
						42	7					33	3
						43	5						
Total	40	Total	40	Total	40	Total	40	Total	40	Total	40	Total	40

INTERNAL ANATOMY

Viscera

The view in Figure 2 is diagnostic of the genus. The folded intestine differentiates the mackerel from the bonito and all members of the Katsuwonidae. The structure of the caecal mass differentiates this form from all the Plecostei.

FIGURE 2. Pacific mackerel: Ventral view of the viscera, *in situ*

In the ventral view of the viscera no one organ dominates the picture. The liver, the caecal mass, the intestine, the air bladder and frequently a ventral fat organ are conspicuous.

Caecal Mass

The caecal mass is a relatively small organ located at the anterior end of the body cavity. It does not extend as far posteriorly as described for other genera. Moreover, this is the only species investigated by the writer in which the individual caeca are large, more or less separated, and empty individually into the duodenum. The individual caeca are loosely enclosed in small groups within an enveloping membrane, but for the most part such groups can be readily separated and

the caeca spread out over the underlying viscera so that the outline of the organ is irregular and changeable. This character alone distinguishes the mackerel from all species of the Plecostei.

The large individual caeca are attached to, and empty into, the duodenum. The latter portion of the intestine is punctured by continuous rows of apertures leading to the individual caeca. The finer structure of these ducts was not investigated and it is possible that several caeca may fuse at their proximal end into a common duct. In relation to the Plecostei the number of caeca is very small and the individual caeca immense.

Liver

The liver is a small and simple organ. It consists of a single, ovoid or triangular lobe with an irregular anterior margin. It lies at the extreme anterior end of the body cavity, invariably to the left of the center line. In some specimens only the mesial margin is seen on the left side, but in most a considerable portion of the liver shows anteriorly in ventral view. In texture and color the liver resembles that of the tunas, but there are no vascular markings of any kind on either surface. Neither are there vascular plexuses associated with the liver. The organ receives only a nominal arterial supply in which respect it is comparable with the bonito. Thus, the liver of *Pneumatophorus* is smaller, simpler and entirely different from that of the bonito and Plecostei and constitutes a positive diagnostic character of the genus.

FIGURE 3. Pacific mackerel: Ventral view of the excised liver

Stomach

This is a relatively slender elongated sack. Its detailed structure was not investigated. In one respect it differs from the comparable structure of all other species investigated. The pylorus arises on the left ventrolateral face of the stomach, near the mid-length of the latter. In the bonito and all members of the Plecostei except *Auxis* the pylorus arises at the anterior end of the stomach. In *Pneumatophorus* the duodenum forms with the stomach a figure resembling a "Y." The pylorus leads posteriorly but almost immediately recurves anteriorly and runs obliquely to the right side and to the anterior end of the body cavity.

Intestine

The intestine has an extensive fold as in the Thunnidae. The origin of the intestine at the anterior end of the body cavity is marked by a constriction of the duodenum and diminished diameter. From this point it runs posteriorly on the right side, generally against the body wall. In cases where the gonads are large this portion and the fold of the intestine are pushed toward the median line. The intestine continues

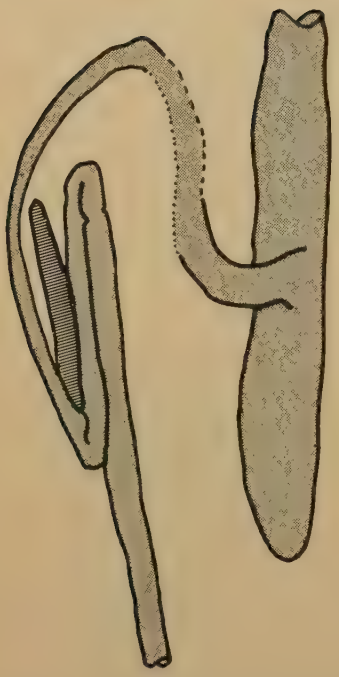

FIGURE 4. Pacific mackerel: Alimentary canal. This illustrates the folded intestine and the posterior origin of the intestinal tract. The horizontally shaded portion is the gall bladder. The course of the duodenum, which was torn in excision, is indicated by broken lines. Actually it is more distended.

posteriorly a distance approximating three-fourths to four-fifths the length of the body cavity. Here it doubles upon itself to form a posterior bend and runs anteriorly to and beyond the posterior margin of the caecal mass. Dorsal to the caecal mass it turns again posteriorly forming an anterior bend and from this point runs with the ascending portion directly to the vent. The fold thus formed lies either on the right side or approaches the center line. The three portions of this fold are adherent, and are loosely contained within an enveloping membrane. In the above respects the intestine of *Pneumatophorus* resembles that of the Thunnidae rather than that of the Katsuwonidae. The intestine terminates posteriorly in an elongated oval vent.

Spleen

The spleen is somewhat amorphous and elongated. It is entirely concealed in ventral view by the liver and caecal mass. In the majority of specimens its outline is difficult to discern for it lies intimately associated with the duodenum and caecal mass. It is extremely delicate and readily disintegrates upon handling. Because of this no consistent and detailed observations were made upon it. In color the spleen is extremely dark red, comparable with that of the tunas.

Gall Bladder

This is a tubular structure located dorsal to the fold of the intestine extending anteriorly beyond this to the loop of the duodenum. Posteriorly it approaches or reaches the posterior bend of the intestine. The anterior end may be expanded into an ovoid sack and the posterior end sometimes tapers to a small diameter. In two arterially injected specimens there was at the head of the gall bladder where that attaches to the duodenum a small ($\frac{3}{16}''$ diameter) spherical sack filled with the injection medium. This was identical in appearance and location in these two specimens. The bile duct was not observed.

Air Bladder

An air bladder is invariably present in this species. It is fairly typical in shape although variable in extent (Figure 5). The dilated portion of the air bladder extends posteriorly about three-fourths the length of the body cavity. It is fusiform in shape, with the posterior extremity drawn out to an indeterminate point. The anterior end is rounded. Posteriorly, the appearance suggests that the air bladder terminates in a hollow connective tissue cord which extends to the extreme posterior end of the body cavity. It looks as though the connective tissue lining of the body cavity met from either side at the posterior margins of the air bladder and thickened gradually to fuse in the mid-line, and into the hollow cord so formed the chamber of the air bladder extends to an indeterminate distance. This was true of all specimens examined. Therefore the length of the air bladder is difficult to measure.

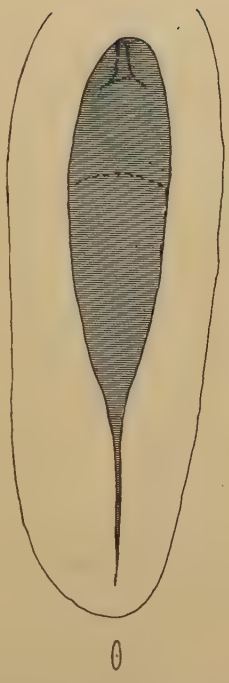

FIGURE 5. Pacific mackerel: Ventral view of the air bladder, *in situ*. The outline of the body cavity is shown for reference. The transverse dotted line indicates the position of the internal septum, and the funnel-shaped outline anteriorly is the concealed duct and its aperture within the bladder.

The internal lining of the air bladder is silvery. An internal septum with a large orifice, comparable with that described for *Neothunnus*, divides the chamber of the bladder into two portions, separating a smaller anterior chamber from the primary posterior chamber of the bladder. This condition is the reverse of that found in the tunas in which the internal chamber is posteriorly located. In *Pneumatophorus* the internal chamber is normally adherent to and bounded by the wall of the body cavity, but in one specimen it was separated from this by a dividing septum and adherent only to the ventral wall of the bladder.

Within this internal chamber is a small crescentic outline in the dorsal wall of the air bladder marking an aperture to a short concealed duct that leads anteriorly, curving towards the right. The function and fate of this duct was not determined but it was noted in all specimens examined. Anteriorly there is no pit beneath the head of the air bladder into which the latter extends. It terminates here on the level of the dorsal wall of the body cavity. In this respect it resembles the bluefin tuna and differs from the yellowfin, bigeye and the albacore. On the anterior ventral wall of the air bladder there is a peculiar "tree-like" plexus (rete mirabile) surrounding the trunk and branches of a small artery originating in the coeliac mesenteric system. This again was seen in all specimens examined. The air bladder of this species is thus diagnostic of the genus in its fusiform shape, its lack of an anterior pit and having the internal chamber anteriorly connected to an inner duct. It is readily distinguishable from all species of the Thunnidae.

Excretory System

Kidney

The posterior kidney mass is a wedge-shaped projection extending approximately two-thirds the length of the body cavity. In outline the margins are strongly serrated and in this respect differ in appearance from that of the bonito and Plecostei. This character alone will separate the genus. There are approximately six such serrations on each side and each of these extends between five and ten mm. beyond the inner margin of the kidney. The margins near the posterior tip of the kidney lack serrations and are more regular and the kidney terminates posterorily in an attenuated apex (Figure 6). Anteriorly the kidney expands in width in the region of the esophagus, but it does not extend into the lateral walls of the body cavity in the pectoral region as does the kidney of the Plecostei and the bonito. In *Pneumatophorus* the kidney tissue is thus confined more or less to the dorsal wall of the abdominal and pericardial cavities. Anteriorly the kidney extends an undetermined distance. This portion was not investigated. Throughout its posterior extent the kidney is relatively thin and lacks appreciable depth. The dorsal aorta appears on the surface of the kidney up to the point where the aorta enters the haemal canal.

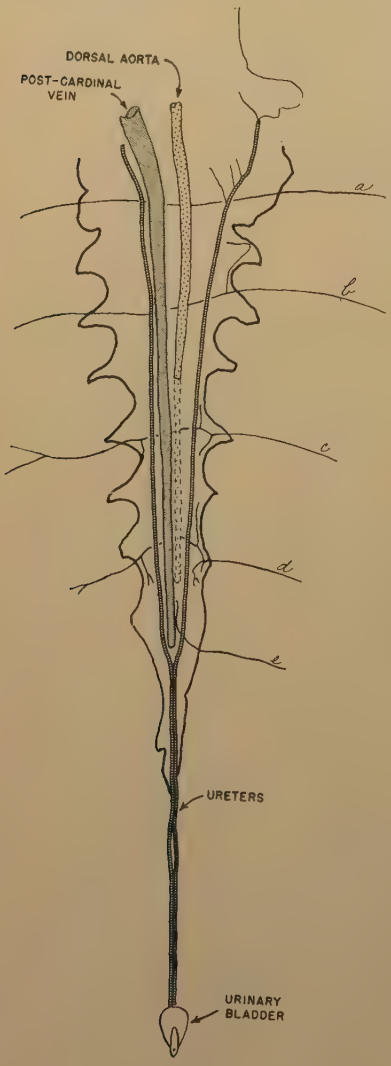

FIGURE 6. Pacific mackerel: Excretory system. The outline is that of the posterior kidney tissue. The vessels labelled, a, b, c, d and e are the segmental arteries, originating in the dorsal aorta beneath the 4th, 6th, 8th, 10th and 11th vertebrae, discussed under the heading "anterior arterial system." The origin of these vessels is shown in Figure 8. The dotted portion of the dorsal aorta is concealed within the substance of the kidney. This portion terminates where the aorta enters the haemal canal.

Urinary Bladder

In *Pneumatophorus* this structure was especially difficult to locate and define. It is a small ovoid thin-walled sack located dorsal to the vent and attached to the approximately vertical portion of the body cavity at the posterior termination of the latter. It was seen only in one or two specimens in which it was especially sought. It differs in shape and ex-

tent from the typical bladder in the Plecostei, and resembles only that of *Auxis* which approximates the condition in this mackerel.

Ureters

Of all structures examined the ureters were the most difficult to locate and define. Routine attempts to inject them were unsuccessful and in only two specimens at the close of this study was the injection of the ureters partially successful. Hence this description is based upon these two injections.

The ureters are small and separate throughout their entire extent. This statement may require modification for it is possible that the two ureters may fuse in an extremely short common duct at the junction with the bladder. This point could not be positively determined. The ureters attach to the bladder through its dorsal wall at or near its anterior tip. From this point, though adherent for the most part, they are divided and the two branches run anteriorly for a distance of approximately one-fourth to one-third the body cavity length. At the point where the postcardinal vein emerges from the haemal canal (through the arch on the 13th vertebra) the two ureters separate and gradually diverge. They run in general well within the substance of the kidney following on each side the margin of the latter. Posteriorly collecting tubules are small and sparse. They increase however in number and size in the anterior portion of the kidney. The anterior course of the ureters differs from anything seen to date. In the region of the heart the ureters curve laterally into the expanded portion of the kidney but recurve abruptly again and run mesially and anteriorly to parallel eventually the dorsal aorta at a distance of roughly one-fourth inch on each side of it. The ureters were dissected and followed anteriorly as far as the orgin of the posterior efferent branchials.

Circulatory System

Visceral Arterial

The coeliac mesenteric artery arises as in all species investigated on the right side. It curves posteriorly around the pharyngeal muscle. Just beyond this (roughly one-half inch from its origin) it gives rise to the exceptionally large No. I branch. The trunk continues posteriorly. At about one-fourth inch beyond, it gives rise to a small vessel which appears to nourish either the right Cuvierian duct or the heart itself. Entering the body cavity just beyond this, the trunk of the coeliac mesenteric artery breaks up into either two or three major branches. This division occurs at the point where the gall bladder attaches to the duodenum. In some specimens the coeliac mesenteric artery divided into two major vessels and in others into three major vessels. In the limited number of injections performed the two types were equally prevalent, and it is not possible to state which is more typical. By anology with other species investigated there should be only two branches here, and the presence of a third distinct branch would constitute a departure from a prevalent fundamental pattern. Two of the three branches when present serve the function of the conventional No. II branch and because of this the writer chooses to interpret two of these as portions of the conventional No. II. In other words a pre-

mature branching of the No. II branch would result in an additional major branch of the trunk. This is interpretive, and there may be significance in the presence of four instead of three major branches in the coeliac mesenteric system.

The present description is based upon one complete injection of a large specimen (452 mm. in body length), supplemented by two partial injections of other specimens measuring approximately 35-40 cm. body

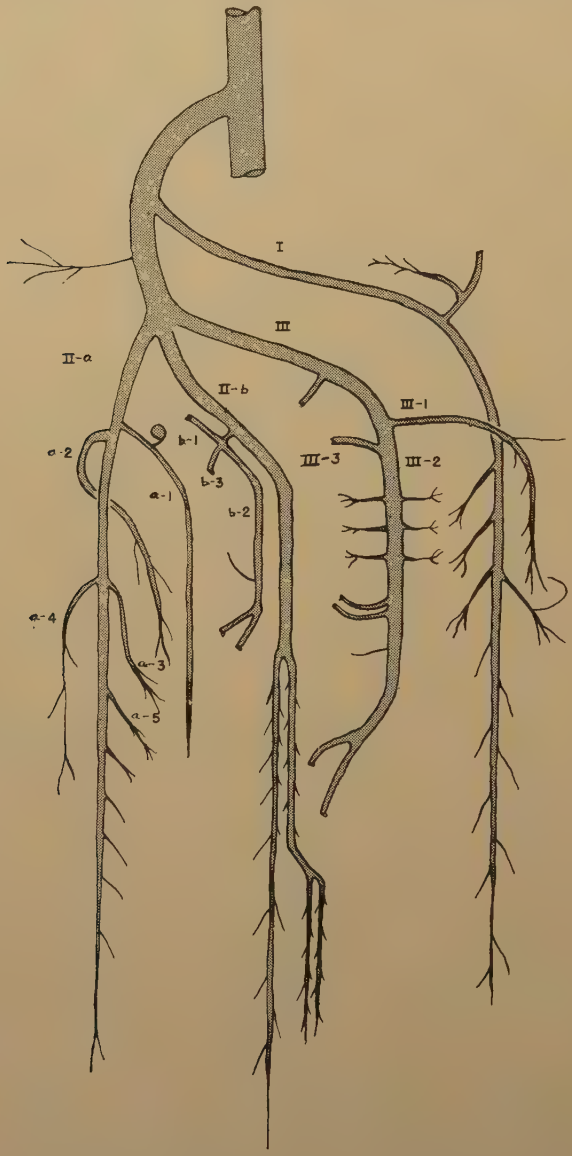

FIGURE 7. Pacific mackerel: Diagrammatic sketch of the coeliac mesenteric artery. The legend conforms to the text.

length. Detailed departures from this can be expected. In Figure 7 the various branches, numbered to accord with this description, are depicted as seen in a particular specimen, whereas the description is inclusive of all injections. This will explain minor discrepancies between text and figure. In particular, branch III-2 which appears in the figure as the trunk of the No. III branch was in the remaining cases one of three divisions.

Beginning with the No. II branch, II-a crosses to the right dorsolateral wall of the stomach and runs thereon to its posterior tip. It gives rise to a number of branches of which a-2, a-3, a-5 and smaller posterior branches run in a ventral posterior direction on the right wall of the stomach. The first branchlet to arise, a-1, runs to the head of the gall bladder and continues posteriorly in the wall of the gall bladder. It is this small branch which is associated with the spherical mass of latex at the head of the gall bladder. Branch a-4 arises from the dorsal face of branch II-a. This small branch runs directly to the ventral wall of the air bladder near its anterior end and thence posteriorly along the mid-ventral wall of the air bladder. It is this vessel that gives rise to the rete mirabile. Branch II-b sends its major supply to the three components of the fold of the intestine. About an inch beyond its origin II-b gives rise to a short moderate trunk which immediately breaks up into three parts. The first or anterior portion, b-1, goes primarily to the duodenum and to individual caeca in that region. This is a complex branchlet which itself branches profusely. One such vessel goes to the straight intestine and runs posteriorly in its dorsal wall. Other small strands from this branch also run to portions of the intestine. The second and third components labeled b-2 and b-3 in the figure go directly to the spleen and constitute its major supply. Beyond the origin of branches b-1, -2, and -3 the main trunk of II-b turns posteriorly and runs in the mesentery enveloping the intestine where it divides into two parallel and adherent strands. One of these follows the straight intestine posteriorly and terminates near the vent in the walls of the rectum while the second runs posteriorly in the fold of the intestine nourishing, through branches, both the ascending and descending portions. Thus the No. II branch through its two major components II-a and II-b supplies mainly the right dorsolateral wall of the stomach, the entire intestinal tract, the spleen and the gall bladder. This is essentially similar to the pattern of the tunas.

The third major constituent of the coeliac mesenteric artery is interpreted herein as the No. III branch. Approximately one-half inch beyond its origin the No. III branch gives rise to a small vessel which runs to the duodenum. Just beyond this the No. III branch breaks up into three components: III-1 runs apposed to the liver towards the pylorus and appears to nourish in its course the caecal mass, but also sends two appreciable strands and probably other smaller ones into the liver; III-3 goes mainly to the anterior caecal mass and appears to ramify throughout the individual caeca. III-2 is the main continuation and the largest component of the No. III branch. It runs dorsal to the duodenum, to and on the dorsal face of the caecal mass giving rise to innumerable moderate branches into this organ. Reaching the pylorus this vessel gives rise to two branches which run in the wall of the pylorus to the stomach. Here they turn anteriorly and nourish the

anterior ventral wall of the stomach. Beyond the origin of these vessels another small one arises and crosses in the mesentery to the fold of the intestine. Branch III-2 finally divides as it approaches the posterior extremity of the caecal mass and both terminal branches cross in the mesentery to the ventral wall of the stomach running posteriorly thereon. Thus, the No. III branch nourishes mainly the caecal mass and the ventral wall of the stomach and secondarily the liver, the duodenum and the intestine. In these respects it is basically similar in pattern to that of the Plecostei.

The No. I branch, whose origin was described earlier, crosses dorsal to the esophagus (or anterior stomach) in the region of the anterior end of the air bladder, and reaching the left side it turns posteriorly on the left dorsolateral face of the stomach. At this point it gives rise to an appreciable vessel which subsequently divides into two parts. One goes ventrally, the other anteriorly into the wall of the esophagus. The No. I branch itself continues in the dorsolateral face of the stomach to its tip, giving rise to approximately four large branches which run posteroventrally in the left wall of the stomach. The fourth or last of these branches is unmistakably connected with the liver by an appreciable arterial strand.

In *Pneumatophorus* there is no connection between the gonads and the coeliac mesenteric artery. The gonads are supplied through the mesentery by segmental arteries arising in the dorsal aorta.

The visceral arterial circulation of this species is similar in basic pattern to that of the Plecostei. It differs in many details from each of the described species and probably could be considered a generic character. However, the writer has examined too few specimens to determine the extent of variation.

Anterior Arterial System

While agreeing in basic pattern with the comparable system of the Plecostei and the bonito, the anterior arterial system of this species is recognizably different in detail. The major difference lies in the fact that there are no cutaneous arteries. Thus, the mackerel, like the bonito, is clearly divided from the Plecostei. Two secondary differences identify the mackerel. The first concerns the efferent branchials. In this genus there is a considerable distance between the points where anterior and posterior efferent branchials join the aorta. This distance is relatively greater than in any species of the Plecostei except *Auxis*. Furthermore the posterior efferent branchials are relatively small, and the accessory vessel arising on each side in the ventral face of the aorta at this point is almost as large as the efferent branchials. In this, *Pneumatophorus* again resembles *Auxis*. The second minor difference is that two vessels arise on each side of the aorta in the mackerel at the point where normally the brachial alone has its origin. The course and appearance of these vessels is superficially identical. Each divides into an anterior and a lateral branch like the brachial of the Plecostei. However the lateral branch of the posterior pair curves posteriorly and appears to terminate in a dendritic system within the substance of the kidney, whereas the comparable branch of the anterior pair continues laterally and ventrally to the pectoral girdle. Hence the anterior pair constitute the brachials, and the posterior pair is peculiar to this species, or possibly the genus.

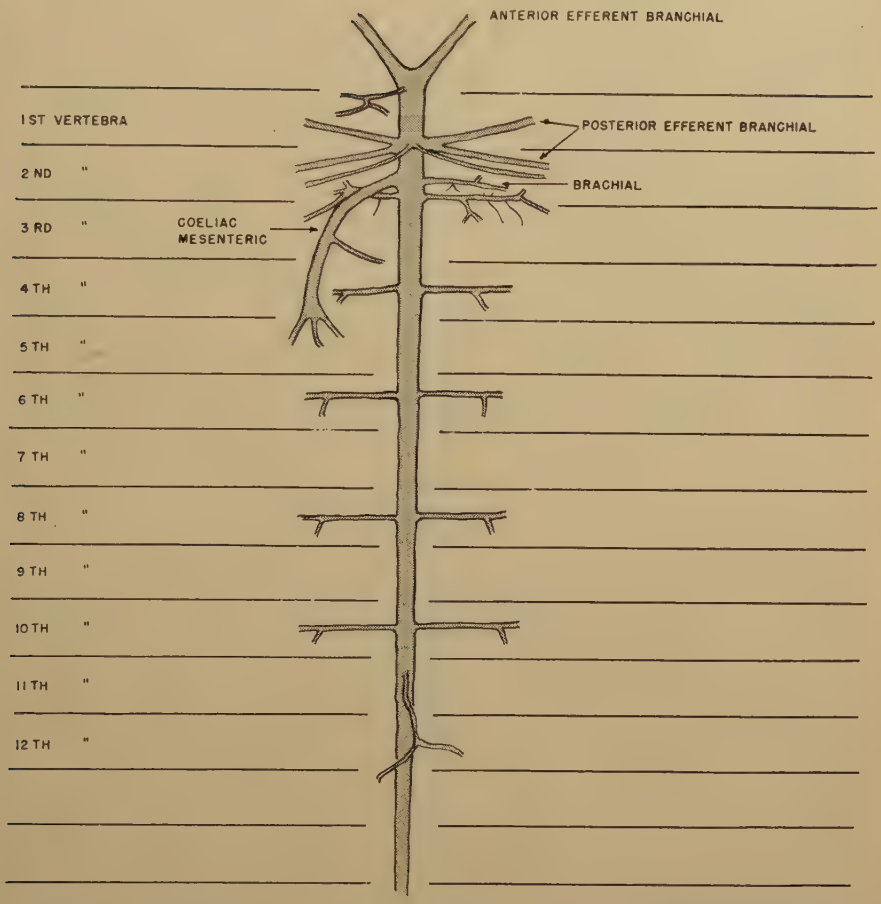

FIGURE 8. Pacific mackerel: Ventral view of the anterior arterial system. The aorta is continued posteriorly to show the origin of the segmentals discussed under this heading.

Posterior to the above vessels no large segmentals arise for an appreciable distance. In fact the dorsal aorta gives off no appreciable vessels posterior to this until it enters the posterior kidney mass. Here it gives rise in alternate segments to four or five moderate vessels on either side which run with the ribs in the body wall and thence through a branch of each to the gonads. These vessels are shown in Figure 6 depicting the excretory system and in Figure 8. In the one specimen investigated, the first pair of large segmentals supplying the gonads arose beneath the fourth vertebra, the second pair beneath the sixth vertebra, the third pair beneath the eighth vertebra and the fourth pair beneath the tenth vertebra. A fifth pair of vessels to the gonads seen in this specimen arose as a single vessel from the ventral surface of the aorta beneath the eleventh vertebra. This vessel, later observed in a second specimen, ran posteriorly in the mid-line to the middle of the twelfth

vertebra where it divided to give rise to a segmental to each side running to the posterior portion of the gonad.

Between the origin of the brachials and the point where the dorsal aorta entered the haemal canal the aorta appeared in some specimens to be displaced slightly to the left of the center line. This was unmistakable. Whether or not this is consistent or characteristic the writer does not know.

The entire anterior arterial system in this genus in relation to the consecutive vertebra is more anterior than in any other genus. The "Y" of the aorta formed by the fusion of the anterior efferent branchial trunks is beneath the occipital region of the skull, just anterior to the first vertebra. The posterior efferent branchials join the aorta at a distance of one vertebra posteriorly namely, beneath the anterior end of the second vertebra. The coeliac mesenteric artery arises just posterior to this beneath the middle of the second vertebra. The brachials, with the supplementary pair described, arise beneath the posterior half of the second vertebra. The large segmentals to the gonads arise respectively, as stated above, beneath the middle of the fourth, sixth, eighth and tenth vertebrae. The first completed haemal arch is on the eleventh vertebra and the dorsal aorta enters the canal through this arch. The postcardinal enters the haemal canal through the arch on the thirteenth vertebra. The body cavity extends to the nineteenth vertebra. It should be emphasized that these statements are based upon the condition in two specimens. Variation must necessarily be anticipated. Actually, the body cavity extends a short distance, probably the length of one vertebra or less, beyond this. In this species the interhaemal spines at the base of the anal fin divide the posterior extremity of the body cavity into two short lateral pockets, as in *Auxis*.[1]

Cutaneous System

There are no cutaneous arteries or veins and nothing remotely comparable with the cutaneous system of the Plecostei.

Postcardinal Vein

A postcardinal vein is present in this species. Its identity was not proved by injection but was assumed by position and appearance. The postcardinal is a large vein whose ventral wall lies exposed as a ribbon of glistening translucent tissue upon the surface of the kidney, so that the vessel is quite apparent even without injection. Upon opening the wall of this vein its detailed course can be readily followed. This large vein emerges from the haemal canal through the arch on the thirteenth vertebra, and as this is usually the third and not the first completed arch, the condition in the mackerel resembles only that in *Sarda* and *Katsuwonus*. In other genera of the Katsuwonidae, and in *Neothunnus* the postcardinal vein emerges from the haemal canal through the first completed arch. Unlike all other species investigated the postcardinal vein of the mackerel does not continue anteriorly in the median line, but trends immediately to the right and lies predominantly on the right

[1] This character in *Pneumatophorus* is not always obvious. In all specimens the interhaemal spines are apparent at the posterior extremity of the body cavity, but the posterior projection of the body cavity on either side is variable. In some it is obvious, while in others it is questionable. It is more consistenly present in *Auxis*.

side of the fish, curving progressively more to the right as it approaches the heart. Its connection with the latter was not investigated. The walls of the postcardinal are entirely devoid of arterial capillaries, in which respect it resembles only *Sarda*.

SKELETON

The skull of *Scomber* (species?) has been minutely described by Allis (1903), while Starks (1910) has described the general osteology of *Scomber* from the Canary Islands and Peru.[2] Although minor differences exist between the present material and the descriptions and illustrations of the authors, there appears to be no reason to duplicate these descriptions. Differences, where they exist, are purely relative, and bones must be described and illustrated relative to comparable bones of similar forms. Such a description belongs in a detailed comparison of the several species of *Scomber* or *Pneumatophorus*. For the purpose of the present study it will suffice to compare the over-all resemblances and differences in the skeleton of the Pacific mackerel with those of the other described species.

Cranium

The skull of *Pneumatophorus diego* is so different from that of the bonito or any member of the families Thunnidae and Katsuwonidae that it can be segregated at a glance. A comparison of the respective illustrations will reveal this. The visual difference lies in the shape and proportions of the skull. That of the mackerel is long, low and narrow, with an attenuated anterior portion, whereas all members of *Sarda* and the Plecostei have a compact, short and relatively deep cranium. In particular, the skull of this mackerel can be positively separated:

a. In lateral view by the fact that the shaft of the vomer touches the parasphenoid only at its distal end, leaving an aperture through the median portion of the snout. Also the frontals do not join the prefrontals in lateral outline to form a continuous anterior lateral margin to the orbit.

b. In dorsal view by the fact that there is a broad elongated foramen separating the frontal bones where they approach the ethmoid.

c. In ventral view by the fact that the mackerel lacks all trace of the prootic pit, and has the myodome almost completely closed posteriorly.

These are merely samples, taken at random, of innumerable positive differences. Such differences overwhelmingly predominate over any resemblance that exists. Accepting this gross difference as obvious and apparent, it is nonetheless of interest to compare the mackerel with the other species in order to see which it resembles most. Again this is a generalized visual comparison and does not relate to particular bones.

In any array of the crania of the several species, the mackerel and any representative of the Thunnidae come at opposite extremes. In over-all proportions, in the absence of the prootic pit and in some

[2] This is most probably *Pneumatophorus peruanus*.

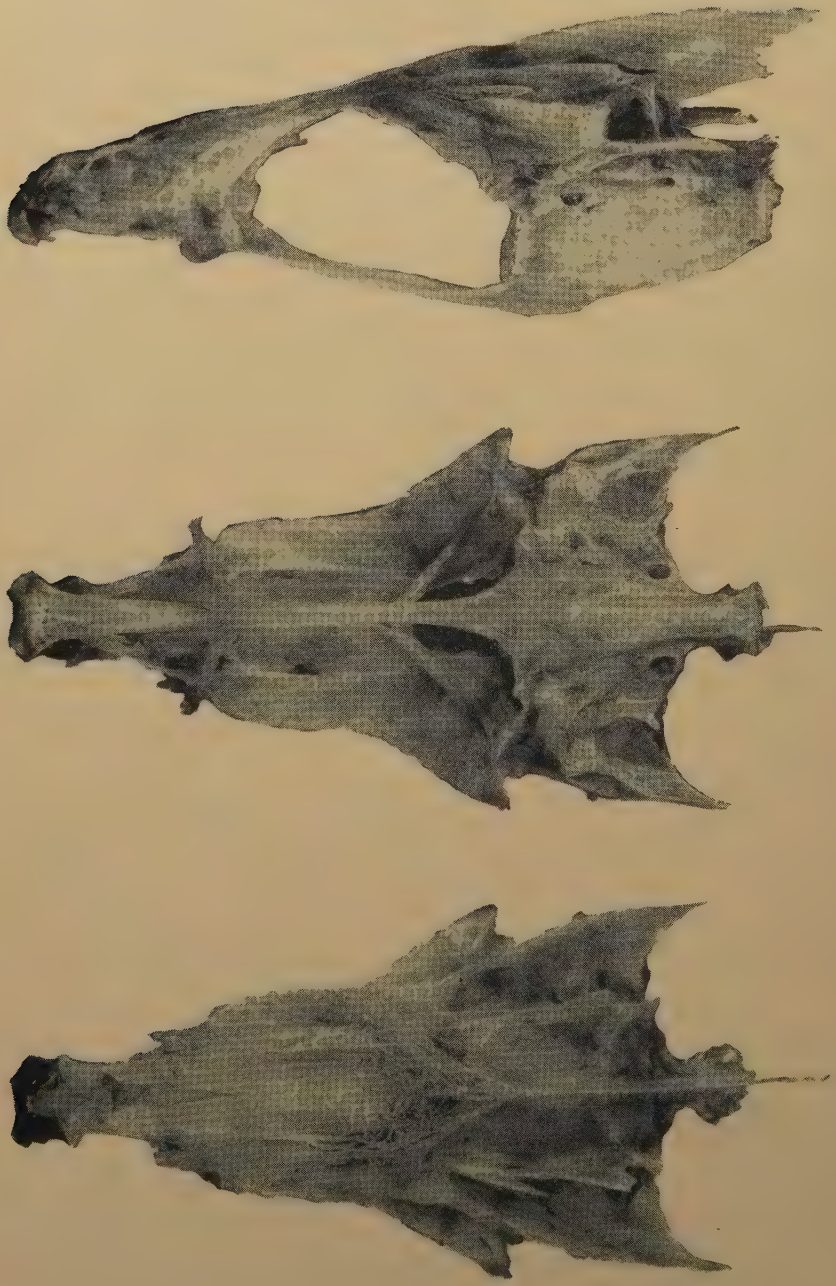

FIGURE 9. Skull of Pacific mackerel: Lateral, ventral, and dorsal vie

details, the mackerel most nearly resembles the bonito. In the lightness of bone, in the low smooth dorsal outline, in the height of the orbit, in the absence of paired foramen in the dorsal posterior region of the frontals the mackerel resembles *Auxis*. There are two suggestive characters worthy of comment. In the Thunnidae and in the bonito the dorsoposterior outline of the cranium in lateral view, along the suture of the exoccipital with the opisthotic, slopes downward at an angle of roughly 45°. In the mackerel this outline is almost vertical. In *Auxis* and in the Katsuwonidae in general this angle is intermediate, and decidedly steeper than in the Thunnidae. In the Thunnidae and to a slightly less extent in the bonito the posterior portion of the skull is foreshortened, in comparison to the mackerel. In the latter the distance from the posterior margin of the orbit to the junction of skull with atlas is over a half, and approximates two-thirds, the greatest length of the orbit. In the Thunnidae and in *Katsuwonus* this distance is less than a half. In *Auxis* and in *Euthynnus* it is again well over a half. In the bonito it approximates but slightly exceeds a half.

Vertebral Column

The vertebral column of this mackerel is quite as different and as distinctive as the skull. The simplicity and uniformity of all neural spines and the lack of expanded anterior ones distinguishes this form immediately. The vertebral count of 31 and the absence of an osseous caudal keel confirm this. The vertebrae are simple and lack the specialization of the Plecostei. The first haemal spine is distinctly "S"-shaped, and the first three are noticeably flattened laterally. The first completed haemal arch is usually on the 11th vertebra. There are 14 precaudal and 17 caudal vertebrae, including the hypural. The only appreciably foreshortened vertebra is that immediately preceding the hypural, whereas in *Sarda* and the Plecostei at least two are thus shortened.

Concerning similarities of the mackerel column with the other described species, the mackerel resembles each in turn in specific characters, but none in general. Lacking a trelliswork on the haemal canal, it resembles *Sarda* and the Thunnidae. But lacking a foreshortened first vertebra it differs from these forms and resembles the Katsuwonidae. Thus for each character of the column a different and often conflicting resemblance can be seen. There is one character, however, that may have significance. The neural canal on all anterior (the first 12 or 13) vertebrae is divided into two distinct and separate canals by a horizontal partition. Figure 11 shows the posterior view of the second vertebra of *Pneumatophorus diego*, and that of the comparable vertebra from a representative of each other group for comparison. Apparently the spinal cord runs in the lower one, while an elastic ligament runs in the upper one. A divided neural canal in anterior vertebrae is likewise common to all members of the Katsuwonidae. Thus in *Euthynnus* the canal is divided in the first six vertebrae. In *Katsuwonus* it is divided on the first and second vertebrae and partially so on the next few. In *Auxis* the first two or three vertebrae have a divided canal and on the next few it is partially divided. In the bonito and in the Thunnidae the neural arch is not so divided in any vertebra.

FIGURE 10. Pacific mackerel: Lateral view of the vertebral column

The individual bones of the skeleton were laid out for comparison, and resemblances noted in tabular form. Where differences were so slight as to render positive identification doubtful, the individual bones were classed as 'similar'. In a listing of 24 separate bones the mackerel was similar to the bonito in three; to the Thunnidae in two, and to *Auxis* in two. *Euthynnus* was differentiated in all, and *Katsuwonus* was not included in this comparison. Such occasional resemblances could be entirely fortuitous, and no significant conclusions can be drawn from this crude comparison. It shows only that the bones of the mackerel manifest no consistent resemblance with any one of the described species, and hence there is no presumptive close relationship between the mackerel and any one of these forms.

FIGURE 11. Posterior view of the second vertebra of representative species to illustrate the division of the neural arch in the mackerel and in the Katsuwonidae. Left to right: *Neothunnus, Sarda, Pneumatophorus, Auxis, Euthynnus* and *Katsuwonus.*

The results of this preliminary skeletal survey indicate that the mackerel, on the basis of skeletal similarity, is far removed from any of the other described groups. In a few respects it resembles *Sarda,* and in others it resembles the Katsuwonidae, especially *Auxis.* Of these casual resemblances the divided neural arch is (in the writer's opinion) the only one meriting serious consideration. As this is present in all the Katsuwonidae and in the mackerel, and absent in all the Thunnidae and in *Sarda,* it must be reconciled in any valid scheme of relationships.

CALIFORNIA BONITO (*Sarda lineolata*)

This description is based upon observations on approximately 20 specimens. Of these, 13 specimens were subjected to detailed examination with the notes specifically recorded; while the balance were used to check particular characters. In the latter case no record was kept of the specimen or its precise origin. All specimens, however, were taken in Baja California, between Cedros Island and Magdalena Bay. Those recorded were taken as follows:

10 Specimens taken November, 1952, from Asuncion Island;
1 Specimen taken August, 1953, from Santa Maria Island;
2 Specimens taken July, 1952, off Abreojos Point;
1 Specimen taken Spring of 1952 off Cedros Island;
1 Specimen taken Spring of 1952, Coast of Baja California.

FIGURE 12. California bonito, *Sarda lineolata*

EXTERNAL CHARACTERS

This bonito is characterized by a series of broad, oblique, parallel black lines on the dorsal half of the body. These lines start in the pectoral region and run posteriorly and upward towards the dorsal outline. The anterior lines are entirely dorsal to the pectoral, but those of the caudal region cross the lateral line and extend to the belly where they gradually fade. In most specimens these lines are regular, continuous, and distinct, and they generally range from 8 to 10 in number. However, the number appears to be quite variable. Although the lines are regular in most specimens, they are not infrequently divided or partial, as shown in Figure 13. Furthermore, the obliquity of the lines is quite variable, and in occasional specimens the lines are nearly horizontal or parallel to the axis of the body. The writer has seen specimens in which the stripes were markedly oblique on one side while on the other they were nearly horizontal. Stripes cannot therefore be considered a positive diagnostic character.

The belly which is normally silvery throughout may, in occasional specimens, have one or more black or dark spots on it. Thus in specimen number eight, of this series, there was a small black spot beneath the tip of the pectoral fin, and a large dark spot just dorsal to the insertion

FIGURE 13. California bonito: This sketch illustrates only the markings, the course of the lateral line and the extent of the corselet

of the ventral fin. These markings were similar to those found on *Euthynnus.*

The corselet extends almost to the tip of the pectoral fin; this was fairly uniform in the specimens examined. The course of the lateral line was casually noted, but not recorded, in the first six dissections; on the seventh specimen a conspicuous break in the lateral line was observed beneath the end of the second dorsal base. In the eighth and subsequent dissections, the course of the lateral line was continuous, so that the interrupted lateral line of number seven is assumed to be the exception. Typically the lateral line trends slightly and gradually downwards from the opercular margin. Immediately over the pectoral insertion it turns abruptly upward to form a wavelike crest. From the crest the line continues posteriorly in a more or less straight line, dropping gradually to the mid-line in the caudal region. Irregular and minor undulations occur. The course in *S. velox* is relatively different, but because of overlapping variation, the difference is indicative and not diagnostic.

The maxillary extends past the vertical through the center of the eye and to, but not beyond, the vertical through the posterior margin of the eye. This character is somewhat variable, and will not positively identify this species. The terminal portion of the maxillary, with the auxiliary maxillary, suggests in outline a broad "U," in which the depth is approximately comparable with the width. This will generally but not invariably distinguish *S. lineolata* from *S. velox.*

The posterior margin of the preoperculum is relatively straight, with the result that the posteroventral aspect of the preoperculum is angular in appearance. Although this was first considered as a distinctive character differentiating *lineolata* from *velox,* it was subsequently found to vary considerably. While there may be a genuine difference in this character in these two species, the character is useless for species identification.

The jaw teeth though relatively large and sharp are smaller than those of *S. velox.* In the upper jaw they are of more uniform size and spacing than in the lower jaw where there are roughly 20 on each side. In this respect *S. lineolata* differs from *S. velox* in which these teeth are larger, more widely spaced and uniform. In *velox* there are approximately 12 teeth on each side of the lower jaw in a fish of comparable size. In both species the two or more anterior teeth on each side of the lower jaw curve mesially and posteriorly (see Figure 40).

The dorsal surface of the tongue is smooth, and there are no lateral ridges. There are no vomerine teeth, and this portion of the roof of the mouth is smooth. However, in some specimens the vomerine ridge can be felt through the skin, so that differing interpretations of this character are possible. Sharp palatine teeth are present in all specimens, and while not excessively developed their presence cannot be overlooked.

FIGURE 14. California bonito: The interpelvic process between the ventral fins. The view on left is typical, while that on the right illustrates an extreme variant.

Inasmuch as Fraser-Brunner (1950) uses the interpelvic process as a generic character, notes on this were made in several specimens. This process is normally divided (Fig. 14) but in one specimen both portions had fused into a single cone. In *Euthynnus* this process was found to be quite variable, and the writer is skeptical about its value as a diagnostic character.

The shape and position of the fins are adequately recorded in Fig. 12. Meristic counts and proportional measurements are recorded in Tables 4 and 5 and will be discussed later. The rays of the first dorsal are uniformly and progressively shorter from first to last, so that the distal outline of the fin is straight. The two dorsal fins are nearly continuous. There are generally eight dorsal and seven anal finlets. The origins of first dorsal, pectoral and ventral fins are almost in the same vertical plane, with the pectoral insertion but slightly anterior to the line joining the other two. The insertion of the anal fish is approximately beneath or slightly posterior to the end of the second dorsal base. The plate of scales surrounding the ventral fins extends for an appreciable distance posterior to the tips of the fins. In three specimens measuring 458, 439 and 441 mm. in body length, this distance was 18, 11, and 11 mm. respectively. This distance is relatively greater than in *S. velox.*

Functional gill rakers are found on the first arch only. On the second arch there are from two to four rudimentary rakers which barely protrude from the angle of the arch. On the first arch there is invariably a raker at the angle, with a developed basal process extending into both the upper and lower limbs. This was overlooked in the beginning of the work, but was checked on all later specimens. The modal count was 8 + 1 + 16, although the mode for the total count on all (11) specimens was 24 (20 — 27). Separate counts on four specimens yielded a range from 7 to 10 + 1 + 11 to 18. The gill raker count is one of the best and most convenient means of separating this species from *S. velox.*

Gill teeth or posterior rakers (internal rakers of Kishinouye) are developed likewise on the first arch only, measuring roughly three or four millimeters in height. On each of the remaining arches there is a comparable series of basal plates, but no developed gill teeth. The

presence of a regular series of gill teeth on the first arch distinguishes this species from *S. velox*.

The vent is an open slit, as in the Katsuwonidae. In stale or distended specimens it may appear round.

INTERNAL ANATOMY

Viscera

As in the tunas the ventral view of the viscera reveals a specific, or at least a generic, pattern. Figure 15 shows the appearance in a typical specimen. The caecal mass, located in the anterior half of the body cavity, is largely enclosed by the three lobes of the liver. The spleen dominates the posterior half. In specimens where the gonads are small the stomach shows between them, posterior to the caecal mass. The gall bladder shows in this view in the majority of specimens. The presence and extent of both the left and right lobes of the liver, the size and location of the spleen, and the view of the gall bladder distinguish this view of the bonito from any of the tunas investigated.

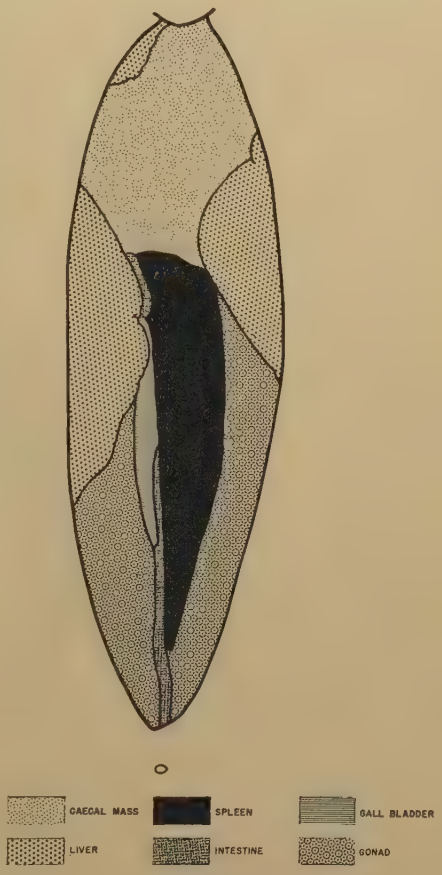

FIGURE 15. California bonito: Ventral view of the viscera, *in situ*

Caecal Mass

As in the tunas, this organ is large and conspicuous. It is generally triangular in ventral view with the apex posteriorly. However, in occasional specimens the apex is lacking, and the shape is more ovoid as in *S. velox*. It is well defined. In mass, it is not as great as the ventral appearance would suggest, for it lacks depth, and is not as massive as in the tunas. The individual tubules are apparently small, or rather, fine, and the surface appearance of the organ is finely striated. The caecal mass is friable and delicate, and invariably breaks apart upon handling. It connects with the duodenal or pyloric region of the alimentary tract by about six ducts, as described for the tunas.

TABLE 4

California Bonito: Meristic Counts Made Upon 11 Specimens

	Fish number										
		No. 12	No. 13	No. 11	No. 4	No. 1	No. 3	No. 8	No. 7	No. 2	No. 6
1st dorsal rays	--	18	19	18	18	18	19	18	18	--	--
2d dorsal rays	--	14	14	14	ca 15	13?	15 or 16	15	14	--	--
Dorsal finlets	--	8	8	9	8	8	8	7	7	--	--
Anal rays	--	12	12	13	12	12 or 13	13?	13	13	--	--
Anal finlets	--	7	7	7	6	7	7	7	7	--	--
Gill rakers:											
Upper limb	7	8	7	7	10	8	10	8	9	9	9
Angle	1	1	1	1	--	--	--	1	--	--	--
Lower limb	16	16	16	16	17	16	15	18	15	17	11
Total count	24	25	24	24	27	24	25	27	24	26	20

TABLE 5

California Bonito: The Measurements Made Upon Eight Specimens, and the Range in the Resulting Ratios, of Which Body Length Is the Numerator in Each Case Except Those Indicated by an Asterisk. In the Latter the Head Length Becomes the Numerator.

	Fish number								
	No. 12	No. 13	No. 11	No. 4	No. 1	No. 3	No. 8	No. 7	Ratios
Body length	439	441	458	489	500	509	647	656	
Head length	115	114	117	126	131.5	137.5	162	163	3.70– 4.02
1st dorsal insertion	114	117	120	129	141	147	178	179	3.46– 3.85
2d dorsal insertion	245	246	255	271	287.5	298	365	377	1.71– 1.80
Anal insertion	283	285	290	312	322	330	429	430	1.51– 1.58
Ventral insertion	131	130	131	137	140.5	153	187	191	3.33– 3.57
Greatest body depth	88	90	95	106	115	117	143	148	4.35– 4.99
Dorsal-ventral distance	84	84	86	93	103	108	131	133	4.71– 5.33
Dorsal-anal distance	188	188	191	207	215	214	283	282	2.29– 2.40
Ventral insertion to vent	152	157	160	173	179.5	175	252	251	2.57– 2.91
Length 1st dorsal base	132	131	138	146	151.5	153	188	197	3.30– 3.44
Length 2d dorsal base	37	41	45	45	45	47	58	60	10.18–11.86
Length of anal base	29	28	34	37	31	39	44	42	13.05–16.13
Pectoral length	53	58	57	62	65.5	69.5	82	85	7.32– 8.28
Height of 1st dorsal	50	49	Broken	ca 43	58	58	59	64	8.62–10.97
Height of 2d dorsal	36	39	40	39	40.5	42	54	55	11.31–12.54
Height of anal	31	36	36	ca 36	40	41	49	54	12.15–14.16
Diameter of iris	12	ca 12	12	13.5	13.5	14	ca 16	16	*9.33–10.19
Maxillary length	56	55	57	60.5	62	64	78	77	*2.05– 2.15 7.84– 8.52
Snout to posterior margin of eye	52	50	53	--	--	--	--	--	*2.21– 2.28 8.44– 8.82

FIGURE 16. California bonito: Ventral view of the excised liver

Liver

The liver differs from that of any of the described tunas in that the right and left lobes are both extensively developed and roughly coextensive, whereas the center lobe is relatively minute. Its appearance in ventral view, *in situ,* is shown in Figure 15 while the excised liver is shown in ventral view in Figure 16. Although approximately coequal in length, the right lobe was slightly longer than the left in all specimens. The center lobe was extremely irregular in outline. There are no conspicuous surface markings on the ventral surface of any lobe, neither small blood vessels such as distinguish certain tunas, nor the large, extensive veins found in *Euthynnus.* In some specimens faint indications of embedded hepatic veins can be seen in ventral view. There are no vascular plexuses associated with the liver as in the genus *Thunnus;* and in contrast with the tunas the arterial supply to the liver is meager. In the above assemblage of characters the liver is therefore diagnostic of this genus.

Stomach

This is a sac-like structure comparable with that described for the tunas. In ventral view it is concealed by the caecal mass, the spleen and by the right lobe of the liver. It extends posteriorly about three-fourths the length of the body cavity in some specimens and almost the full length of the body cavity in others.

Intestine

The intestine is straight as in *Katsuwonus, Euthynnus* and *Auxis,* without the fold characterizing the Thunnidae. As in the tunas, the caecal ducts enter the duodenal or pyloric region of the intestine. The intestine arises on the left side of the stomach anteriorly, traverses its ventral face and turns back at the anterior end of the body cavity to run directly back to the vent without any fold. Normally the intestine lies on the right side of the fish, but in specimens in which the gonads are large and developing the intestine is pushed into the center line.

Spleen

The spleen, *in situ* (Figure 15), lies ventral to the stomach, and its posterior end projects freely into the body cavity. The anterior end may lie dorsal to the caecal mass, with its margin thus obscured, or it may lie ventral to the latter so that its entire outline is seen in ventral view. It is roughly wedge-shaped, with the point of the wedge posteriorly. The anterior end is generally rounded and expanded. In the great majority of specimens the surface was distinctly mottled with fine mark-

ings, giving it a drab olive hue. As in *S. velox* this mottling is due to pigments in the enveloping membrane, and when the latter is removed the spleen tissue is of the typical deep reddish-black color. The spleen disintegrates rapidly after death, and in all but freshly caught or promptly frozen specimens the organ becomes diffuse through liquifaction upon thawing, and loses all semblance of its original shape and texture. The spleen is probably longer in this species than in *S. velox,* and its posterior tip is certainly closer to the vent. The distance from the tip of the heart to the posterior tip of the spleen, related to the length of the body cavity, ranged from 0.77 to 0.93. In association with other organs of the viscera, the size, location and appearance of the spleen are distinctive characters of the genus.

Gall Bladder

This is a dark green tubular structure which is generally, but not invariably, seen in the ventral view of the viscera, *in situ.* It is associated with and parallels the straight intestine and right lobe of the liver. It was not subjected to comparative observations in this species.

Air Bladder

There is no air bladder in this species.

Excretory System

Kidney

The shape of the kidney (Figure 17) resembles that of *Katsuwonus* and *Euthynnus.* The posterior extension is a long, narrow wedge of crenulated tissue extending approximately three-fourths or more the length of the body cavity. In some specimens the margins were ill defined but regular, with no apparent crenulations. Embedded in the midline of its ventral surface, throughout the greater portion of its length, is the large postcardinal vein. The substance of the kidney envelopes this vessel dorsally. Anteriorly the kidney extends into the pectoral region where it expands laterally as in the tunas, but this portion of the organ was not investigated. Of itself the shape of the kidney is neither distinctive nor different.

Ureter

The single ureter enters the urinary bladder through its dorsal wall at an appreciable distance, usually about one cm.

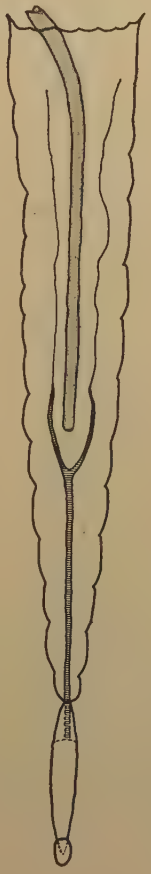

FIGURE 17. California bonito: Excretory system. The postcardinal vein is shown emerging from the haemal canal and running anteriorly between the two branches of the ureter. The outline is that of the posterior kidney mass.

(in a fish approximately 50 cm. in body length) from the anterior end. Traversing the heavy sheath of connective tissue lining the dorsal wall of the body cavity, the ureter runs anteriorly into the substance of the kidney and continues until it approaches the postcardinal vein as that emerges through the haemal arch on (approximately) the 18th vertebra. Here, approximately beneath the 19th vertebra, the ureter divides into two branches which, on either side, run anteriorly parallel to the postcardinal vein. The two branches are small, somewhat erratic in their course, and in comparison with the tunas they resemble the collecting tubules of the latter rather than the trunk of the ureter. The discussion of the excretory system and the postcardinal vein of *S. velox*, to which the reader is referred for further detail, applies to this species also.

Urinary Bladder

The urinary bladder is an inconspicuous organ largely concealed by the gonads. This is particularly true of females in which the gonads fuse poteriorly. Throughout its length, the bladder is adherent to the dorsal body wall, and is enclosed laterally and probably ventrally by the membrane of the gonads. The bladder is relatively long, and in three specimens measured 42, 39 and 35 mm. in over-all length, which was respectively 0.24, 0.23 and 0.20 of the body cavity length. In these three specimens the ureter joined the bladder 12, 10 and 8 mm. from its anterior tip, and in each case the ureter continued in the bladder wall as a roofed duct for a distance of four mm., before actually opening into the bladder.

While the excretory system described above differs in many details from that of other genera, it does not positively identify the bonito from all other genera investigated. Beyond the fact that the ureter in its undivided extent, appeared relatively larger than in *S. velox*, no actual differences in the two species were noted.

Circulatory System

Anterior Arterial

Figure 18 illustrates this system in a typical specimen. It is essentially similar to all the investigated species, with one fundamental difference. There are no cutaneous arteries. This fact places the bonito into a group—or family—separate and distinct from the Thunnidae or Katsuwonidae.

In the majority of specimens the anterior efferent branchials unite in a "Y" beneath the junction of the first and second vertebra, or beneath the anterior end of the second vertebra. The posterior efferent branchials join the aorta beneath the anterior half of the third vertebra. The coeliac mesenteric artery originates beneath the junction of the third and fourth vertebra. The brachials, small to moderate in size, arise on either side just posterior to the coeliac mesenteric artery beneath the fourth vertebra. Just posterior to the coeliac mesenteric artery and the brachials, a characteristic ligament encircles the aorta on its ventral and lateral faces, as described for the tunas. A pair of pharyngeal muscles which attach to the fifth, sixth and portions of the seventh vertebrae enclose the aorta laterally, posterior to the origin of the coeliac mesenteric artery. The aorta is not conspicuously constricted at any point, and continues posteriorly as a large vessel, entering the

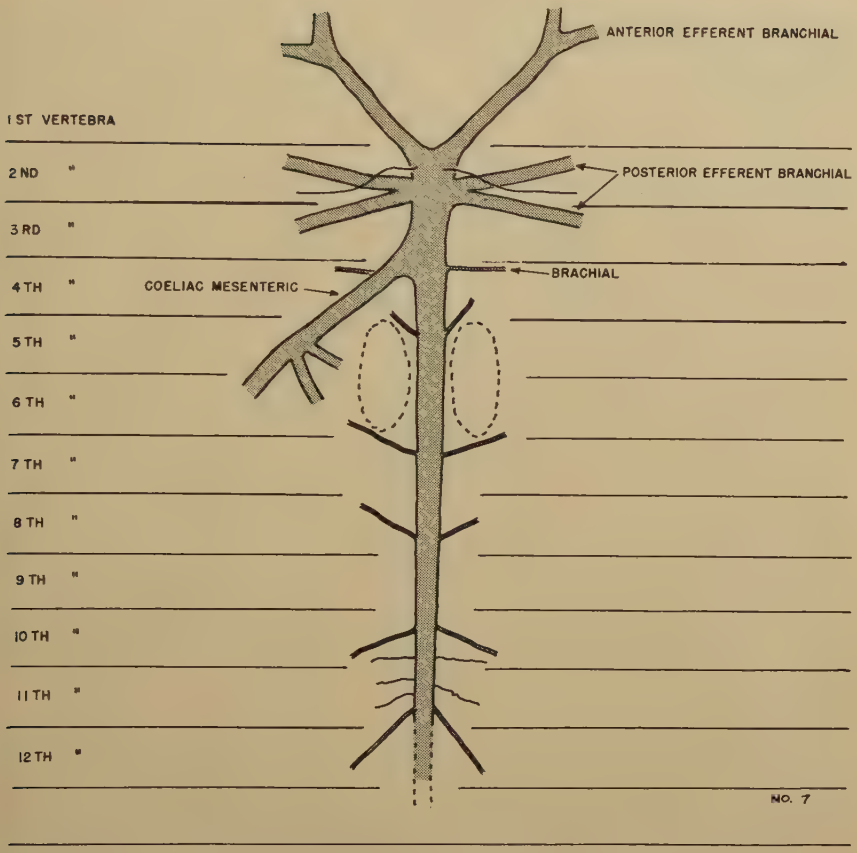

FIGURE 18. California bonito: Anterior arterial system. The dotted oval outlines are the pharyngeal muscles.

haemal canal through the first completed arch, which in the majority of specimens is on the 13th vertebra.

Between the origin of the coeliac mesenteric artery and the 12th vertebra, the aorta gives rise to numerous small paired vessels. When possible each of these vessels was followed in each specimen to determine whether or not any one of them could be considered homologous to the cutaneous arteries of the Thunnidae and Katsuwonidae. In every case these vessels ran either into the kidney substance where they broke up to nourish the surrounding tissue, or through the kidney into the wall of the body cavity. Each of the pair sent a portion of its supply through a branch to the vicinity of the vertebral column. Posteriorly, the last such pair was often conspicuous. It originated laterally, usually beneath the 11th vertebra, just before the aorta entered the haemal canal. Each vessel of the pair ran posteriorly at an oblique angle with the aorta into the kidney substance, in which it broke up, sending some small branches into the adjacent musculature. In this it differed from the majority of the preceding paired vessels, all of which either turned

anteriorly or at least sent branches anteriorly. In no case did any such vessel continue to the surface musculature. There is in the bonito no cutaneous artery, or cutaneous vascular system, as described for the tunas.

Visceral Arterial

The viscera of the bonito are supplied with arterial blood entirely by the coeliac mesenteric artery. The gonads only, receive blood from the aorta. The coeliac mesenteric artery originates in the dorsal aorta on the right side, and runs laterally before turning posteriorly to divide in the vicinity of the heart into two branches, the No. II and No. III. In the bonito the No. I branch originates generally in the trunk of the No. II just beyond this division. Five specimens were sufficiently injected for an examination of this system, and in one of these the No. I branch originated in the trunk of the coeliac mesenteric artery prior to the origin of the two remaining branches.

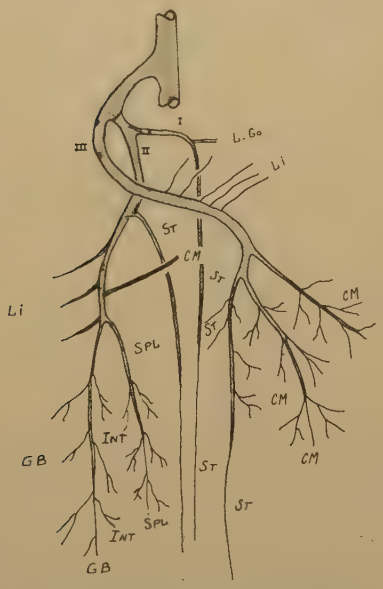

FIGURE 19. California bonito: Diagrammatic sketch of the coeliac mesenteric artery. CM = caecal mass. GB = gall bladder. Int = intestine. L. Go = left gonad. Li = liver. Spl = spleen. St = stomach.

From its origin in the No. II branch, the No. I branch runs transversely to the esophagus. It crosses on the dorsal wall of either the esophagus or the anterior portion of the stomach, to the left side of the fish and runs posteriorly on the left dorsolateral wall of the stomach to its extremity.

In one of the five specimens adequately injected, a small vessel originated in the No. I branch and ran to the left gonad. It is possible that a comparable vessel was present, but overlooked, in the remaining specimens. In the tunas, such a vessel is also present.

The No. II branch runs to the right lobe of the liver. Just prior to reaching this organ it gives off a moderate branch which runs posteriorly in the right dorsolateral angle of the stomach to its tip.

Reaching the right lobe of the liver the No. II trunk runs posteriorly as a large single vessel in the mesentery enclosing the liver but not within the substance of the liver as in the tunas. It gives off only one or two moderate and other small capillary-sized vessels which enter the right lobe of the liver, whereas in the tunas a major portion of its supply goes into the liver. In its course paralleling this lobe of the liver, the No. II branch sends one moderate and numerous small vessels into the caecal mass. Beyond this point, the trunk of the No. II branch runs posteriorly in the membrane enveloping the spleen, the intestine and the gall bladder, to which organs its remaining supply goes. In some

specimens the intestine and gall bladder are nourished by numerous small branches of the main vessel which eventually disappears within, and ramifies throughout, the substance of the spleen. In other specimens the trunk divides into two parallel vessels, one of which divides its supply between the intestine and gall bladder, while the second goes entirely to the spleen. The No. II branch thus nourishes the right lobe of the liver, a portion of the caecal mass, the right dorsolateral wall of the stomach, the gall bladder, spleen and intestine.

The No. III branch runs to the body cavity dorsal to the heart, and thence to the center lobe of the liver, giving off one or more small vessels to the dorsal wall of the esophagus. Reaching the liver, it gives rise to a number of small vessels which run into the substance of the center and left lobes of the liver. Beyond this the vessel curves posteriorly, to enter the substance of the caecal mass. As it does so it gives rise to a large branch which runs laterally to the left on the ventral face of the caecal mass upon which the liver is superimposed. As in *S. velox,* this vessel was difficult to locate and follow. Apparently it runs to and nourishes the left lobe of the liver.

The substance of the caecal mass is profusely supplied with branching and anastomosing vessels from the No. III branch. It is extremely difficult to determine the pattern and course of the several branches. However, there appear to be three main divisions which are shown diagramatically in Figure 19. Two of these vessels nourish mainly the caecal mass. Undoubtedly finer vessels from this system emerge from the caecal mass and nourish contiguous portions of the alimentary canal and the liver. The third branch of this trunk runs through the caecal mass giving off numerous small vessels to its substance, and emerges again intact posteriorly to cross in the membrane to the ventral wall of the stomach, on which it runs to its posterior extremity. Hence, the No. III branch nourishes the caecal mass, and secondarily the ventral wall of the stomach and the center and left lobes of the liver.

In this system the bonito resembles the Katsuwonidae more than the Thunnidae, but differs from both families in one important respect. In the Thunnidae, and to a lesser extent in the Katsuwonidae, the liver is characterized by an extremely rich blood supply, and in extreme cases by the development of complex and extensive vascular plexuses. This characteristic is entirely lacking in the bonito, in which the liver receives but a nominal arterial supply, whereas the caecal mass receives the major supply. This suggests that the liver of the tunas and to a less extent that of the Katsuwonidae, dominates the visceral metabolism of the individual, whereas it plays a subordinate role in the case of the bonito. Alternatively, there may be an inverse correlation in size of liver with blood supply. While this is speculative, it is none the less a fact that the bonito is characterized by an extremely large liver which receives only a nominal arterial supply, in contrast to the tunas which have a relatively small liver profusely supplied with arterial blood. To this extent the bonito can be distinguished from the Thunnidae and Katsuwonidae by the visceral arterial system.

One other peculiarity of the visceral blood supply needs recording. The right gonad is supplied with arterial blood through a large vessel

originating in the dorsal aorta. This vessel enters the body cavity through the substance of the kidney, beneath the eighteenth vertebra at the point where the poscardinal vein emerges from the haemal canal. Within the substance of the kidney this vessel divides into two. The branch on the left side turns anteriorly and breaks up into numerous branchlets which nourish the kidney, while the branch on the right side leaves the kidney and enters the right gonad. It appears therefore that the right gonad receives arterial blood from the axial system, whereas the left gonad receives its supply from the No. I branch of the coeliac mesenteric artery. However, these observations are isolated and need confirmation.

In the above respect this description differs from that of *S. velox,* wherein the right gonad receives arterial blood from a small vessel originating in the trunk of the No. III branch. In the dissection of the specimens of *velox,* such an axial vessel from the aorta to the right gonad was never seen.

In no case is there recorded in the dissectional notes of *S. lineolata* an observation of a connecting vessel between the No. I and No. III branches, such as was regularly seen on the left side of the stomach of *S. velox.* It is possible that the two species differ in these respects. But because they are both difficult of observation and depend on near-perfect injections, too much significance should not attach to these seeming differences. The fundamental pattern of arterial visceral circulation is similar in the two species.

Cutaneous

There is no cutaneous system, either venous or arterial, in the bonito, such as characterizes the families of the tuna and skipjack. There is a broad wedge of dark meat along the lateral line, but this, and the myotomes are nourished by segmental vessels originating in the dorsal aorta and running laterally toward the surface with the intermuscular bones. There is a conspicuous segmental of moderate size in every other vertebral segment, and alternating with these there is on each remaining vertebral segment a small and inconspicuous artery. The appearance in these specimens suggests that these segmentals grow larger in the posterior region of the body. Many of them are divided into two smaller parallel strands, and although the veins were not injected, the appearance of such divided arterial vessels is reminiscent of the tunas in which the arteries are so frequently divided into two parallel strands separated by an accompanying vein.

Approaching the surface the segmentals break up into numerous minute vessels, and a transverse section of the lateral musculature shows a cluster of arterial strands at the apex of the wedge of blood meat beneath the lateral line. Hence, in the bonito the lateral blood meat is nourished by segmentals from the axial system.

Postcardinal Vein

A large, conspicuous postcardinal vein is present in the bonito. It emerges from the haemal canal through the arch on the eighteenth vertebra, and runs anteriorly along the mid-line in the substance of the kidney. In this region its ventral wall is exposed, or covered only by a thin layer of kidney tissue. Approaching the heart the postcardinal

turns to the right and with the large veins from the head enters the right Cuvierian duct. In the two or three specimens carefully examined there were no perforated membranes, so characteristic of the tunas, at the junction of the postcardinal with the Cuvierian duct. The vein opened directly into the duct.

The postcardinal vein of the bonito differs in a number of significant respects from that of the other genera investigated. It does not run entirely within the haemal canal. Whereas the first completed haemal arch is generally on the thirteenth vertebra, the postcardinal vein emerges from the haemal canal after traversing the arch on the eighteenth vertebra, and angling ventrally, it continues anteriorly ventral to the haemal arches, embedded in the substance of the kidney. At the point of its emergence the postcardinal is joined by a smaller renal vein running anteriorly in the mid-line from the distal portion of the kidney. In consequence of its ventral course and its premature emergence the postcardinal is completely separated from the dorsal aorta anterior to the eighteenth vertebra. A second resulting difference distinguishes *Sarda* from any member of the families Thunnidae and Katsuwonidae. The walls of the postcardinal (and, in fact all large veins in *Sarda*) are entirely devoid of the enmeshing arterial capillaries so characteristic of these two families. The contrast is striking. Thus, the postcardinal will serve to separate the bonito from any species in either family.

MEXICAN BONITO (*Sarda velox*)

EXTERNAL CHARACTERS

This description is based upon four specimens taken at Tagus Cove, Albemarle Island, Galapagos Group, on February 12, 1953. Of these specimens all were examined superficially and three were subjected to a detailed examination. These four specimens ranged from 433 to 457 mm. in body length and all subsequent references to distances or measurements relate to fish of this size.

This bonito can generally be recognized by the six to eight closely

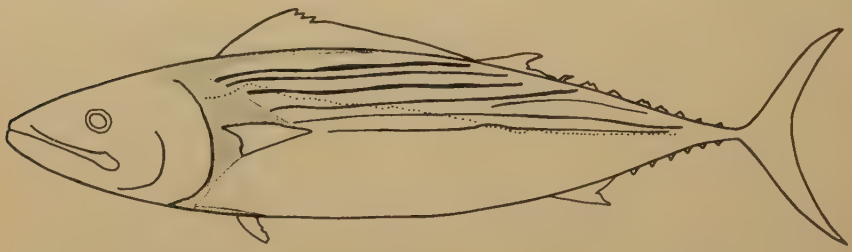

FIGURE 20. Mexican bonito: The outline in this drawing merely serves to orientate the markings, the course of the lateral line and extent of the corselet and maxillary

spaced longitudinal black stripes on the dorsal half of each side. These stripes, which start anteriorly in the pectoral region and continue to the caudal region, are generally continuous, but some may be interrupted or partial. The flanks and belly are silvery, without color markings, and in no case did the dorsal stripes extend onto the belly.

The corselet is short, and extends to, but not beyond the tip of the pectoral fin. There was little apparent variation in this. The scaled plaque enclosing the ventral fins is likewise short, and extends not more than four millimeters beyond the tip of the ventral fin. It thus differs from *S. lineolata* in which it is generally longer.

From the margin of the operculum the lateral line runs horizontally or slightly downward for a short distance; just beyond the pectoral insertion it rises to a wavelike crest. The slope of this rise is roughly 45 degrees, and the height of the crest is approximately a half inch. In *S. lineolata* the rise is more abrupt and sometimes precipitous. However, there is considerable variation in this angle, and in one specimen of *velox* the rise was as steep as that of the majority of California bonito. From the crest of this rise the lateral line slopes gradually downward. Its course is fairly regular, lacking consistent or pronounced undulations. Anomalies in the lateral line are common and no systematic significance is implied. Thus, in one local, and in one Galapagos specimen, there was a definite discontinuity in the lateral line on one side of each fish.

The maxillary extends beyond the vertical through the posterior margin of the eye. In *S. lineolata* the maxillary extends to this vertical but not beyond it. Likewise the shape of the distal portion of the maxillary will distinguish the majority of specimens of these two species.

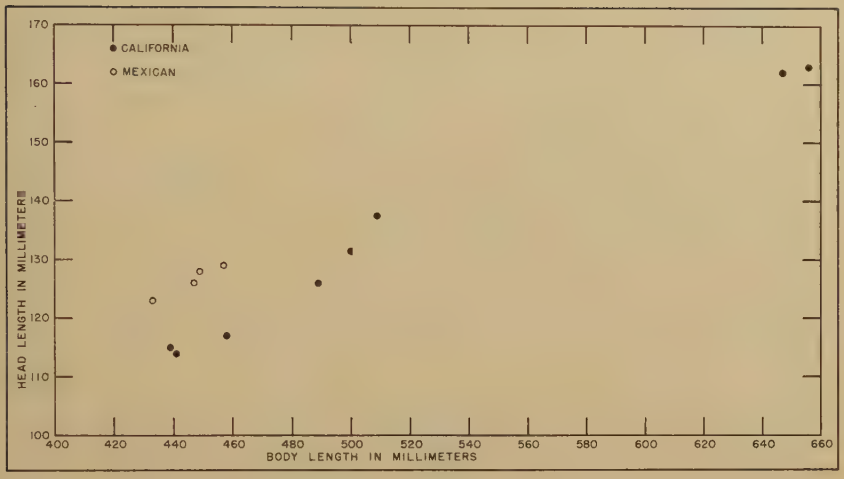

FIGURE 21. The regression of head length on body length in *S. lineolata* and in *S. velox*

In *S. velox* the maxillary, with the auxiliary maxillary bone, forms in outline a narrow, deep, oblique "U". In *S. lineolata* the "U" is more circular. This character, though not infallible in itself, affords one of the most convenient means of identifying the species.

The posterior margin of the preoperculum is generally more rounded than that of *S. lineolata*, with the result that the posteroventral outline is less angular. This character, however, is quite variable, some-

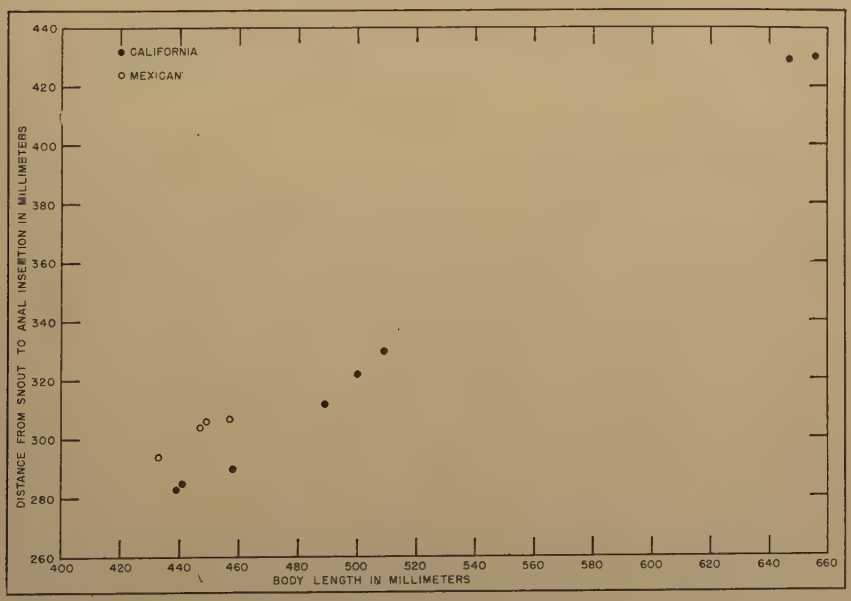

FIGURE 22. The regression of anal insertion on body length in *S. lineolata* and in *S. velox*

what elusive and at best a corroboratory one. Photographs and sketches of specimens are apt to be misleading, because the appearance of the preoperculum depends upon the aspect from which it is viewed. The outlines of the preoperculum in Figures 13 and 20 are not intended to illustrate this difference.

The teeth are visually and numerically different. In this species they are noticeably larger, more regular and fewer in number than in *S. lineolata*. Using the count on the left side of the lower jaw there were usually 12 distinct large teeth in *S. velox* compared with 19 to 21 in *S. lineolata*. In *S. velox* there are occasionally a few small teeth inter-

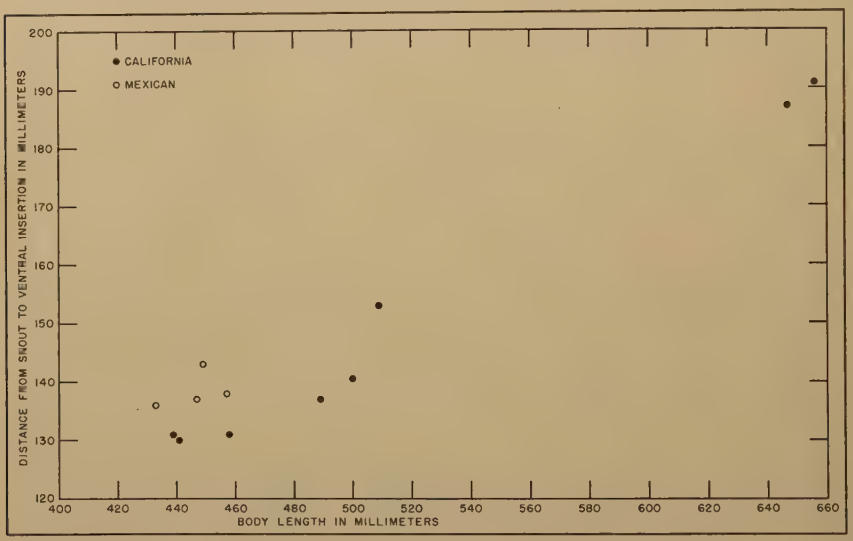

FIGURE 23. The regression of ventral insertion on body length in *S. lineolata* and in *S. velox*

spersed between the larger ones, and the maximum count observed was 15 (see Figure 40).

Palatine teeth, though not quite so prominent as those of *S. lineolata*, are invariably present and unmistakable. There are no vomerine teeth. The tongue is without the dorsally projecting lateral cartilaginous ridges found in the tunas.

The interpelvic processes were casually observed, and appeared divided as in *S. lineolata*. The fins were in no way distinctive in this species.

The measurements of the four specimens are tabulated in Table 6. The head length is relatively greater in *S. velox* than *S. lineolata*. The ratio of head length in this species, to body length fell between 3.51 and 3.55, whereas in *S. lineolata* it ranged from 3.70 to 4.02. The insertion of the anal fin is slightly more posterior, falling roughly on the vertical through the insertion of the first dorsal finlet or between the first and second dorsal finlet. In *S. lineolata* the anal insertion is below the end of the second dorsal base, or between this and the first dorsal finlet. The ventral fins are more posteriorly inserted than in *S. lineolata*.

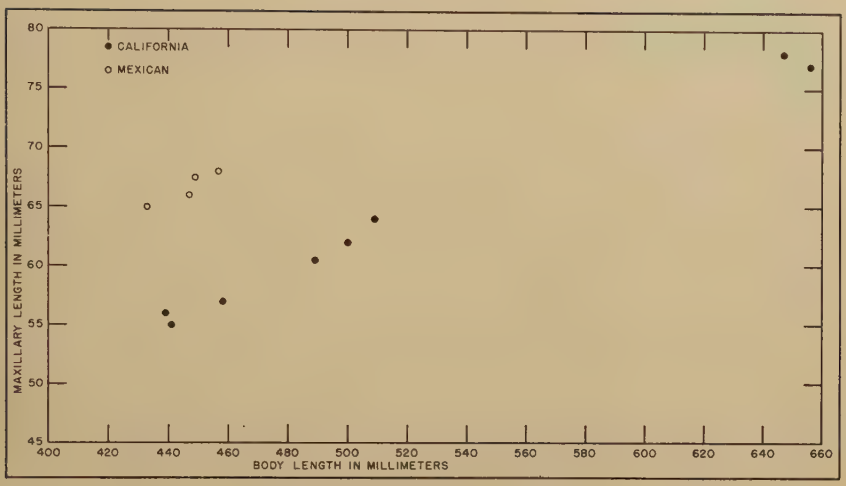

FIGURE 24. The regression of maxillary length on body length in *S. lineolata* and in *S. velox*

The maxillary is appreciably longer in *S. velox,* both in relation to the head and to the body length. Similarly the eye in *S. velox* is proportionately larger in relation to the head; and in relation to both head and body length the hinder margin of the eye is more posterior.

The various counts made are tabulated in Table 7. The modal number of anal rays appears to be higher than in *S. lineolata,* while the number of anal finlets is one less. This will be discussed in a later comparative section.

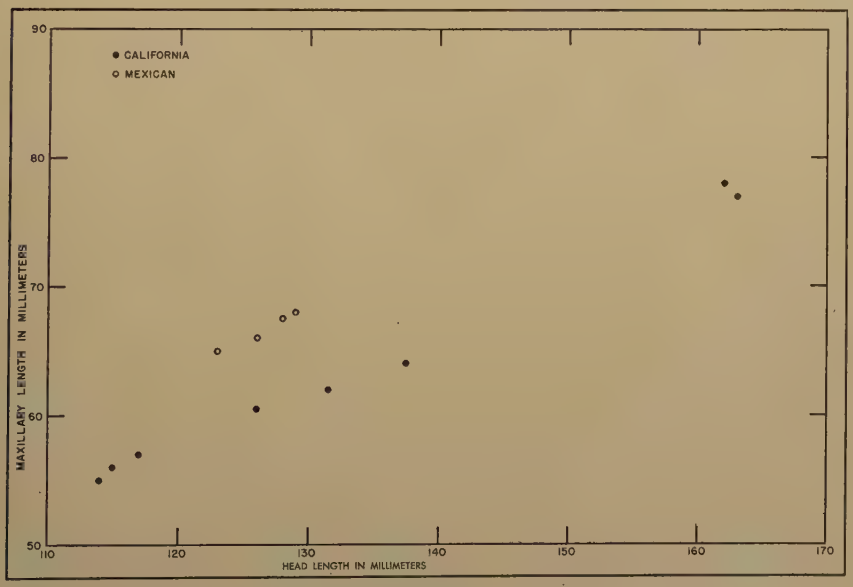

FIGURE 25. The regression of maxillary length on head length in *S. lineolata* and in *S. velox*

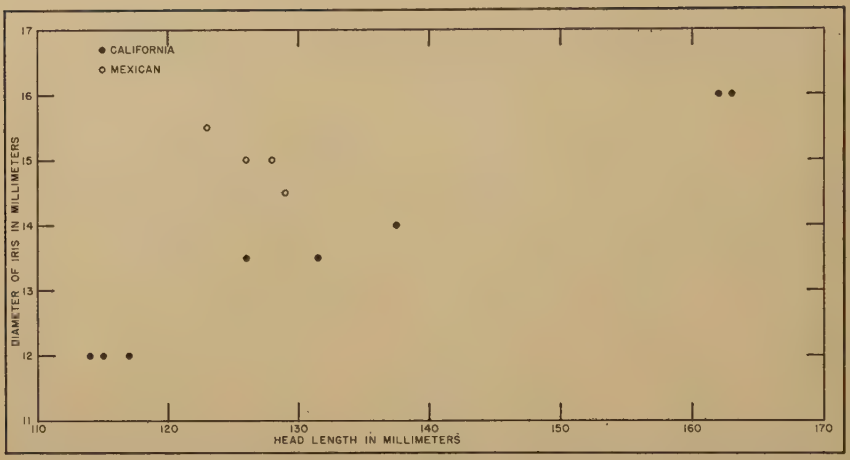

FIGURE 26. The regression of diameter of iris on head length in *S. lineolata* and in *S. velox*

There are functional gill rakers on the first arch only. Rudimentary rakers may be found on the angle of subsequent arches, but these are minute, consisting generally of mere basal protuberances. There is invariably a raker at the angle of the first arch, with a basal root projecting into both the upper and lower limb. The count was 3(2-3) + 1

TABLE 6

Mexican Bonito: The Measurements Made Upon Four Specimens, and the Range in the Resulting Ratios, of Which Body Length Is the Numerator in Each Case Except Those Indicated by an Asterisk. In the Latter the Head Length Becomes the Numerator.

	Fish number				
	Gal. No. 2	Gal. No. 1	Gal. No. 3	Gal. No. 4	Ratios
Body length	433	447	449	457	
Head length	123	126	128	129	3.51– 3.55
1st dorsal insertion	125	130	132	131	3.40– 3.49
2d dorsal insertion	249	265	259	263	1.69– 1.74
Anal insertion	294	304	306	307	1.47– 1.49
Ventral insertion	136	137	143	138	3.14– 3.31
Greatest body depth	95	97	96	96	4.56– 4.76
Dorsal-ventral distance	90	94	90	90	4.76– 5.08
Dorsal-anal distance	193	201	198	200	2.22– 2.29
Ventral insertion to vent	165	170	167	172	2.65– 2.69
Length 1st dorsal base	126	139	130	137	3.22– 3.45
Length 2d dorsal base	41	45	41	43	9.93–10.95
Length of anal base	31	35	35	34	12.77–13.97
Pectoral length	58	59	59	ca 60	7.47– 7.61
Height of 1st dorsal	42	ca 53	46	42	9.76–10.88
Height of 2d dorsal	36	43	37	42	10.40–12.14
Height of anal	35	40	37	39	11.18–12.37
Diameter of iris	15.5	15	15	ca 14.5	*7.94– 8.90
Maxillary length	65	66	67.5	68	*1.89– 1.91
					6.65– 6.77
Snout to posterior margin of eye	59	60	62	ca 62	*2.06– 2.10
					7.24– 7.45

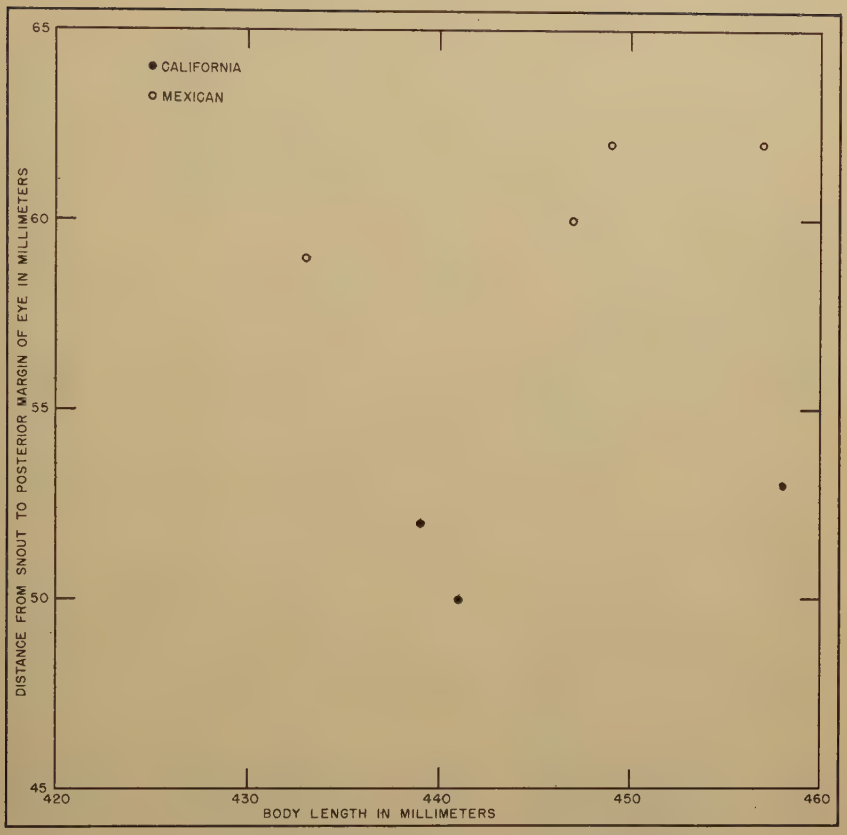

FIGURE 27. The regression of the measurement, snout to posterior margin of eye, on body length in *S. lineolata* and in *S. velox*

$+ 6(5\text{-}8) = 10(8\text{-}11)$. This compares with a total count of 24 rakers in *S. lineolata*. It should be emphasized that the count in *S. velox* includes only those structures that rise unmistakably from the arch. The count does not include mere basal plates or protuberances that cannot be elevated from the arch. If such were included the relative counts in two fish, for example, would be: $4 + 1 + 8 = 13$ instead of $3 + 1 + 6 = 10$, and $3 + 1 + 8 = 12$, instead of $2 + 1 + 5 = 8$.

There are no developed gill teeth or posterior rakers on any arch, though basal plates are present and approximately equally developed on all arches. This statement needs qualification, because there are actually a few rudimentary teeth on the upper arm of the first arch with occasionally one or two at, or just below, the angle of the arch. These rudiments can be seen in profile, but the longest did not exceed one mm. in length. In contrast with this, *S. lineolata* has short distinct gill teeth on both limbs of the first arch. These gill teeth are two to three millimeters in height and are regularly distributed throughout the length of the arch. Their identity cannot be mistaken. Thus the absence of such rakers in *S. velox* is a positive diagnostic character.

TABLE 7

Mexican Bonito: Meristic Counts Made Upon Four Specimens

	Fish number			
	No. 1	No. 2	No. 3	No. 4
1st dorsal rays	19	17	18	18
2d dorsal rays	15	16	16	15
Dorsal finlets	8	7	8	9
Anal rays	15	14	16	15
Anal finlets	6	6	6	6
Gill rakers:				
Upper limb	3	2	3	2
Angle	1	1	1	1
Lower limb	7	8	6	5
Total count	11	11	10	8

INTERNAL ANATOMY

Viscera

This view, shown in Figure 28, is essentially similar to that seen in *S. lineolata.* The visceral organs are, however, relatively shorter. This impression is substantiated by measurements, which show that, in relation to the length of the body cavity, the lobes of the liver, the stomach, the caecal mass and the spleen, all project posteriorly a lesser distance than in *S. lineolata.* This view is diagnostic of the genus, but not of the species.

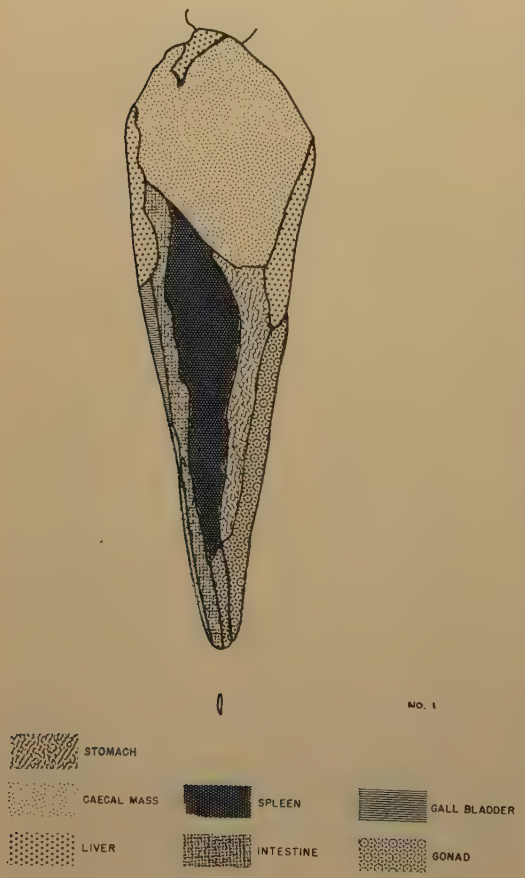

FIGURE 28. Mexican bonito: Ventral view of the viscera, *in situ.* Posteriorly, the right gonad overlies the left.

Caecal Mass

This is a relatively short, ovoid organ, lacking generally the posterior apex of *S. lineolata*. The enclosed caecal tubules are fine, and characterize the superficial appearance. It is a fairly compact organ, and is not divided into adherent lobes. Neither is it intimately attached to adjacent organs, except at its head, where it is difficult to separate from the head of the liver.

Liver

This organ consists of three lobes, of which the right and left are long and attenuated, with the right slightly the longer. The center lobe is distinct but small. In the ventral view of the viscera, *in situ,* the center lobe invariably shows, as illustrated, and the terminal portions of the left and right lobes generally but not invariably can be seen. There are no conspicuous surface markings, but faint indications of the course of hepatic veins can frequently be seen in one or more lobes. No conspicuous arteries or arterial networks can be seen on the surface. The liver receives only a nominal supply of the visceral arterial blood, and lacks entirely the complex circulation of the Thunnidae and Katsuwonidae.

FIGURE 29. Mexican bonito: Ventral view of the excised liver

Stomach

In the three specimens available, the stomach was shorter than in *S. lineolata,* but beyond this observation no detailed study was made of this organ.

Intestine

The intestinal tract originates in the pylorus on or to the left of the mid-ventral line of the stomach. The duodenum continues to the left side of the fish, then loops anteriorly and transversely to the right side of the fish. Reaching the anterior end of the body cavity the duodenum becomes constricted and as the intestine turns posteriorly and runs directly to the vent without folds or convolutions. The intestine is relatively small in diameter, and shows no clear evidence of division into functional parts. The caecal ducts, roughly six in number enter the posterior face of the duodenum but there appears to be one compound duct entering its anterior face.

FIGURE 30. Mexican bonito: Ventral view of the excised spleen

Spleen

This is a conspicuous organ lying in the center line in the posterior half of the body cavity. Its shape is illustrated in Figure 30. The broad, rounded anterior end may be ventral or dorsal to the margin of the caecal mass. In this species the spleen, although similar in shape, does not extend as far posteriorly as in *S. lineolata,* averaging in three specimens 0.74 of the length of the body cavity. In most specimens the surface of the spleen is finely mottled with an olive hue. This mottling is due to pigments in the enveloping membrane. When this is removed the exposed surface of the spleen tissue appears dark red as in the tunas.

Gall Bladder

This is an elongated tubular structure, dark green in color, tapering at both ends from a greatest diameter near its mid-length. Anteriorly there is no clear distinction between gall bladder and bile duct, the former tapering gradually into the bile duct which is large and conspicuous. The posterior portion of the bladder lies in the membrane enveloping the intestine, but anteriorly the bladder is more closely associated with the right lobe of the liver. The bile duct runs anteriorly with the right lobe of the liver and then curves mesially and posteriorly to enter the pyloric region. There is nothing specifically distinctive about the gall bladder, although it is generically different.

Air Bladder

There is no air bladder.

Excretory System

Kidney

This is a long narrow wedge of tissue extending from the pectoral region almost the full length of the body cavity (Figure 31). In all cases it continued posteriorly beyond the anterior tip of the urinary bladder, and in one instance a narrow strand of kidney tissue extended the remaining length of the body cavity. As in *S. lineolata* the kidney is very narrow and is confined to the mesial region of the dorsal wall. In the pectoral region it expands abruptly to the lateral walls, but this portion was not studied. The outlines of the kidney are fairly straight and regular, there being only slight crenulations in its margins. In all respects it appeared similar to that of *S. lineolata.*

Ureter

The single or fused ureter joins the urinary bladder a short distance from its anterior tip. In two specimens this distance was six and nine millimeters. The ureter does not open directly into the bladder, but runs a short distance posteriorly in its dorsal internal wall, and opens as in the tunas through a tunnel-like channel. From the bladder the ureter can be followed directly through the heavy connective tissue lining of the body cavity and thence anteriorly in the mid-dorsal line. Meeting the posterior tip of the kidney the ureter enters this organ and continues anteriorly as a single vessel for an appreciable distance before dividing. In the three specimens examined this division occurred 60, 76, and 78 mm. from the anterior margin of the vent. This distance is equivalent to 0.3 and 0.4 of the body cavity length, and the division of the ureters is on the vertical through the 20th to 22d vertebra. The vent, marking the end of the body cavity, was on a vertical drawn through the 29th vertebra.

FIGURE 31. Mexican bonito: Kidney and ureter. The postcardinal vein is shown anteriorly from the point where it emerges from the haemal canal. Joining it at this point is a small renal vein.

The two branches of the ureter run anteriorly, roughly parallel and five to ten mm. apart. Reaching the 18th vertebra, the ureters meet the postcardinal vein as that emerges from the haemal canal and for a distance they run anteriorly, separated by the width of the postcardinal or slightly more. In this region they are moderate in size and fairly straight in course. More anteriorly, they diverge irregularly from the postcardinal, their course becomes erratic and even zigzag in some cases, and they are progressively and appreciably reduced in size. As the postcardinal swings laterally to the right of the fish to join the right Cuvierian duct, the right ureter follows it and the left ureter follows a comparable course on the left side of the fish. At this point, in one specimen, the right ureter (or perhaps only a branch of it) was actually in the wall of the postcardinal. The terminal portions of the ureters are minute and branching, and commence in the lateral kidney mass in the pectoral region.

Throughout their course, the ureters, both the branches and the fused trunk, are deeply embedded in the kidney substance in the bonitos, more so than in the Katsuwonidae and Thunnidae. They receive innumerable collecting tubules in all planes. In general the ureters are small, attaining their greatest diameter at the point of convergence. The fused trunk, running posteriorly from the point of convergence, appears to become smaller and at the point where it joins the bladder it

is difficult to locate. This difficulty is enhanced by a striking peculiarity of the bonitos. An injection of the ureters invariably resulted in a partial venous injection of the postcardinal and renal system. How this occurs the writer does not know. The fact that in every (three Galapagos and several local) case the injection mass, introduced with certainly into the ureter, found its way into the postcardinal and renal veins, indicates some interconnection between these two systems. To avoid any doubt regarding the identity of the actual vessel injected, the needle was in one instance inserted through the urethral aperture in the urinary bladder, with the same results. The course of the veins so injected will be described in connection with the postcardinal system.

The ureters of *S. velox* are essentially similar to those of *S. lineolata* and no consistent differences were observed.

Urinary Bladder

This is a tubular structure at the extreme posterior end of the body cavity. It lies between the gonads, adherent throughout to the dorsal wall of the body cavity. Because of its close association with the gonads and the membranes enveloping them the bladder was generally difficult to locate and discern. This was particularly true of gravid females, in which the gonads are fused posteriorly and conceal the entire bladder. Apparently the testes do not so fuse, and the bladder was easier to observe in males.

In the three specimens the urinary bladder was relatively long, measuring 33 mm. in two specimens, which is equivalent to 0.18 of the body cavity length. The bladder is relatively uniform in width, but tapers posteriorly into a duct. The opening of the ureter into the bladder was difficult to find, though the point of attachment and the apparent aperture could be plainly seen when the ventral wall of the bladder was opened and laid back. The apparent aperture is covered by a delicate membrane, which forms a roofed passage within the bladder for a distance of several millimeters. The excretory system of this bonito is not specifically distinguishable from that of *S. lineolata*, and resembles, in general, that of *Euthynnus*. Differences are relative.

Circulatory System

Anterior Arterial

This system was observed in some detail in order to determine whether or not there was anything comparable with the cutaneous arteries of the tunas.

The dorsal aorta arises in the fusion of the anterior efferent branchials. This occurs beneath the junction of the first and second vertebra. The major vessels arising in the aorta are comparable with those described for other species. The posterior efferent branchials fuse on either side and through a short common trunk join the aorta beneath the junction of the second and third vertebra. Just posterior to this the coeliac mesenteric artery arises on the right side either beneath the junction of the third and fourth vertebra, or under the anterior portion of the fourth vertebra. The brachials arise almost simultaneously, beneath the anterior or middle portion of the fourth vertebra. That of the left side arises in the lateral face of the aorta while the right

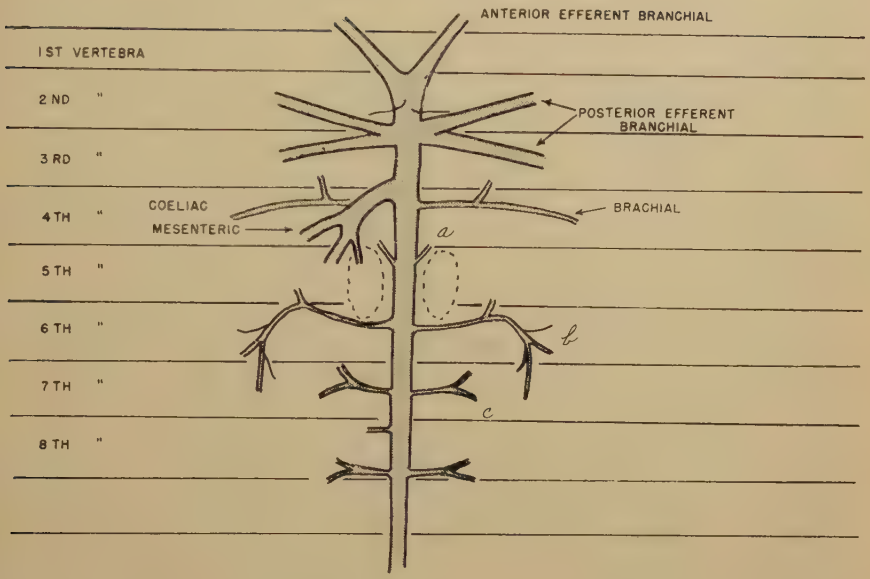

FIGURE 32. Mexican bonito: Anterior arterial system. The vessels arising immediately posterior to the dotted pharyngeal muscles are segmentals and not cutaneous arteries.

brachial arises beneath (dorsal to) the coeliac mesenteric artery on the dorsolateral or even dorsal face of the aorta. Because there is no cutaneous artery, the coeliac mesenteric is the last of the large vessels originating in the aorta. The pharyngeal muscles attach to the sixth vertebra extending to the posterior portion of the fifth vertebra.

In addition to these major vessels a number of small vessels arise adjacent or posterior to the pharyngeal muscles. The more obvious and characteristic ones are illustrated in Figure 32. These are paired, and arise from the lateral face of the aorta in successive body segments. The first pair ("a" in the sketch) posterior to the brachials runs diagonally forward. The second pair ("b") runs laterally across the ventral face of the pharyngeal muscles and then divides. The third pair ("c") likewise runs laterally and duplicates the course of "b." Between these pairs, smaller and irregular arterial strands arise and run into the substance of the kidney. Posterior to "c" other segmentals arise. Their course is similar to that of "c," and is not further considered.

Because the interest in this study focuses about an adequate definition of the term "tuna" and on the relationships of such species as the bonito, the homology of vessel "b" with the cutaneous artery of the Plecostei was investigated. The vessel "b" arises in the same relative position as does the cutaneous artery, and like the latter, "b" runs laterally through the kidney tissue toward the surface musculature. Could this be indicative of the evolutionary origin of the cutaneous system?

In all specimens the vessel "b" arose beneath the sixth vertebra. In all specimens it ran laterally across the ventral surface of the pharyn-

geal muscle. At the lateral margin of this muscle it divided into either two or three branches. What appeared to be the largest branch turned dorsally, traversed the lateral face of the pharyngeal muscle and continued toward the vertebral column. Its terminal fate was not followed. The second branch continued laterally and then ventrally and ran between the first and second ribs towards the surface musculature. It terminated in numerous fine branches within the muscles and did not actually reach the surface. From the origin of this second branch a third branch arose in some cases, and supplied the adjacent kidney tissue.

The vessel "c" followed a comparable path, sending its major supply around the base of the pharyngeal muscle to the vicinity of the vertebral column, and a lesser supply in a vessel which followed the ribs ventrally. Appearances suggested that those segmentals posterior to "c" followed a similar pattern.

The resemblance of this incipient pattern with the cutaneous system of *Euthynnus* was heightened by the course of the brachial. This vessel (in both *S. velox* and *S. lineolata*) arises and divides in a manner characteristic of the tunas. One branch runs anteriorly towards the cranium, while the main trunk runs laterally through the anterior kidney tissue and then posteriorly to the pectoral girdle and pectoral insertion. On one of three specimens this portion of the brachial sent a small branch beyond the pectoral insertion to the surface musculature. The terminal branches of this small vessel barely reached the surface, but the general course and pattern of the brachial was strongly reminiscent of *Euthynnus,* in which this vessel as often as not gives rise to the ventral cutaneous branch. Emphatically there is no cutaneous system in the genus *Sarda,* but the above observations suggest a potential evolutionary origin of such a system.

The anterior arterial system of *S. velox* is not distinguishable from that of *S. lineolata.* The dissections however yielded the impression that the segmentals "b" and "c," and possibly others posteriorly, were larger proportionately than in *S. lineolata.*

Visceral Arterial

The coeliac mesenteric artery arises on the right side, either beneath the fourth vertebra, or under the junction of the third and fourth vertebra. Within a quarter to a half inch of its origin it divides into three branches as in the Plecostei (Figure 33).

The No. I branch, although smaller than the others, is fully developed. It originates in the No. II branch at the origin of the latter and runs posteriorly with the No. II branch for about one fourth of an inch. Then the No. I branch turns mesially and crosses to the left side in the dorsal wall of the stomach. Reaching the left side it turns posteriorly and runs the length of the stomach in its left dorsolateral wall. Anteriorly, the No. I branch is joined by a small vessel that emerges from the left lobe of the liver, and arising in that portion of the No. III branch supplying this lobe. In the same general region the No. I branch gives rise to a small vessel which runs in the mesentery directly to the

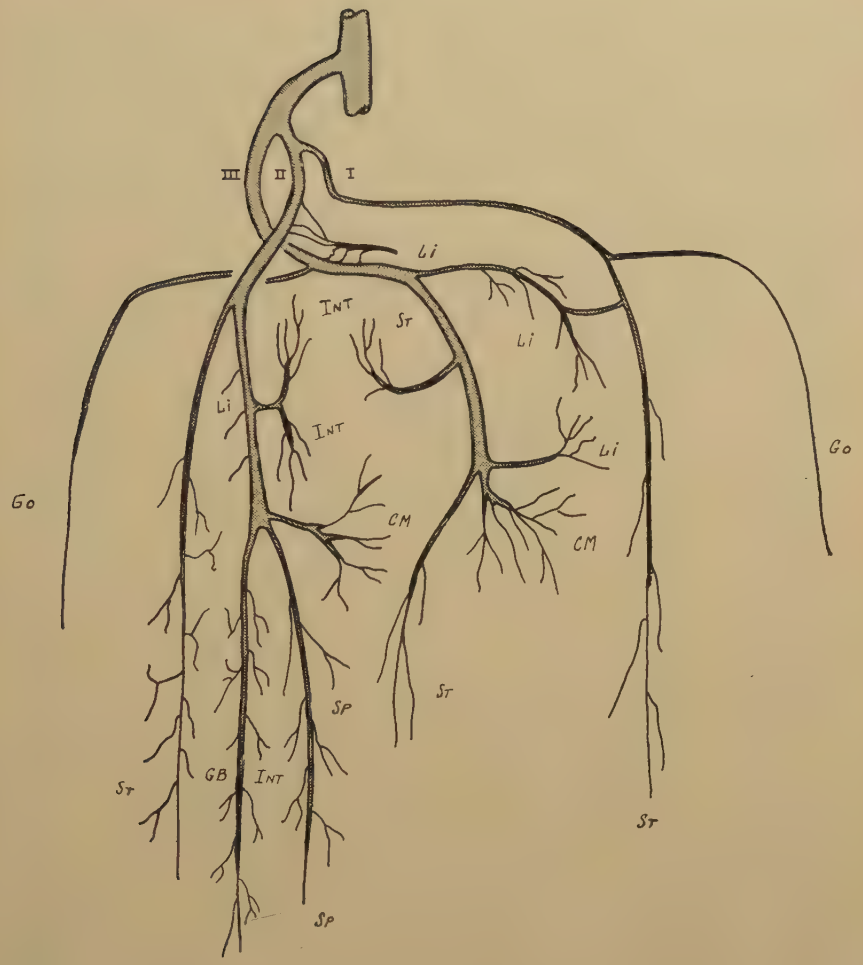

FIGURE 33. Mexican bonito: Diagrammatic sketch of the coeliac mesenteric artery. Cm = caecal mass. Gb = gall bladder. Go = gonad. Int = intestine. Li = liver. Sp = spleen. St = stomach.

left gonad. The No. I branch is the simplest of the three, and as in the tunas its main function is to nourish the left side of the stomach.

The No. II branch at its origin is mesial to the No. III. It runs posteriorly to the right anterior wall of the stomach, trending ventrally in its course. In this—its undivided—extent it gives rise to a number of small tributary vessels, some of which go directly into the head of the liver while others fuse with similar tributaries arising in the No. III branch to form a larger single discrete vessel which runs into the head of the liver.

Reaching the right wall of the stomach the No. II branch divides. The smaller branch is dorsal, and continues in the right dorsolateral face of the stomach wall to its posterior tip. This vessel nourishes both the adjacent surface muscles of the stomach and the deeper or internal

layers. The larger branch of the No. II trends ventrally and runs in the mesentery between the right lobe of the liver and the intestine. As it continues posteriorly it gives off a number of arterial strands into the right lobe and then a moderate branch which crosses, perpendicularly, to the intestine. Reaching this, the latter divides into an anterior and a posterior branch both of which fan out over the intestinal walls. The trunk (of the No. II) from which this branch arises continues posteriorly in the mesentery and shortly divides into three major branches. One goes into the caecal mass, ramifying throughout the distal portion of its dorsal surface; the second goes intact to the spleen and breaks up therein into a comprehensive network, while the third branch continues posteriorly in the mesentery nourishing principally the intestine and gall bladder. In one injection this vessel ultimately crossed to the spleen and entered its distal extremity.

The No. III branch is the most difficult to follow. From its origin it runs posteriorly and ventrally, lateral to the No. II. However, approaching the liver the No. III branch trends mesially and crosses ventral to the No. II branch, giving rise to a small, easily overlooked vessel which runs in the mesentery directly to the right gonad. Just beyond this the No. III branch gives rise to the tributary strands, discussed above, which fuse with strands from the No. II to form the separate vessel to the head of the liver. Beyond this the No. III trunk disappears within the substance of the liver. Although it is not deeply embedded, and remains intact, one has to tease away the liver—and subsequently the caecal mass—tissue to follow its course. In this extent it gives rise to innumerable fine strands into the head of the liver, and apparently one major branch which is the principal arterial supply to the left lobe. The precise origin of this vessel is obscure. The trunk of the No. III continues to the pyloric region passing posteriorly between pylorus and stomach wall. Here it is inextricably associated with caecal mass, caecal ducts and the duodenal loop, to such an extent that it cannot be followed without severing some of these structures. At this point it gives off innumerable minor vessels to the duodenum, the intestine, and principally to the caecal mass, and in addition a series of arterial strands which fuse into one or more separate and discrete vessels which cross in the mesentery to the anterior ventral wall of the stomach. There were indications in one specimen that a separate and small vessel arose here likewise and entered the left lobe of the liver.

Beyond this the No. III branch continues posteriorly to, and then in, the dorsal face of the distal caecal mass, giving rise in this extent to an extensive and complex vascular system which permeates this entire portion of this organ. Here the No. III branch bifurcates into two terminal vessels. One remains in the caecal mass and branches over the entire distal portion, while the other crosses in the mesentery to the ventral wall of the stomach. This vessel runs posteriorly in the ventral wall to the tip of the stomach. It sends branches over the ventral surface and into the stomach.

A small vessel emerges from the left lobe of the liver and runs dorsally in the mesentery to the left stomach wall. It connects directly with the No. I branch as that runs posteriorly in the left stomach wall. Since the former vessel must arise in the No. III branch, the bonito thus shows a characteristic common to many of the tunas.

The visceral arterial circulation in this species is essentially similar to that of *lineolata*. A minor character that might differentiate the two species concerns the arterial supply to the right gonad. In *velox* this comes—in part at least—from the coeliac mesenteric system, whereas such a source was not demonstrated in *lineolata*.

Cutaneous System

There is no cutaneous system in this species, nor anything comparable with it. The dark meat about the lateral line is nourished by segmentals originating in the aorta. Thus the bonitos are clearly separated from all members of the Plecostei.

Postcardinal Vein

The postcardinal vein is a large conspicuous vessel which emerges from the haemal canal through the arch on the 18th vertebra and thence runs anteriorly in the mid-line within the substance of the kidney to the region of the heart. Here it curves to the right of the fish and discharges directly into the right Cuvierian duct. In this genus there are no perforated membranes or complicated structures at the point of confluence.

In size, course and location the postcardinal is identical with that of *S. lineolata* and similar to that of the Katsuwonidae. A character peculiar to the genus *Sarda* is the emergence of the postcardinal from the haemal canal, not through the first completed arch, but through the arch on the 18th vertebra, which is roughly the sixth completed haemal arch. Anterior to the 18th vertebra the postcardinal is completely removed and separated from the dorsal aorta. Likewise the postcardinal of *Sarda* lacks completely the complex arterial network within its walls. No trace of an arterial injection can be seen in the walls of the postcardinal.

At the point where the postcardinal turns ventrally to emerge from the haemal canal (usually the 18th vertebra) it is joined by a renal vein coming from the distal portion of the kidney. The origin of this vein was not explored, but at the point where the ureter joins the urinary bladder the renal vein is already a moderate vessel, as large in fact as the ureter. It runs anteriorly into the kidney tissue with the ureter, and is closely associated with the latter throughout its extent. At the point where the postcardinal emerges from the haemal canal the renal vein divides into two, and sends an enveloping arm on either side of the approximately perpendicular postcardinal. These apposed branches of the renal vein enter the postcardinal on opposite sides as that vessel turns horizontally to run anteriorly.

Both the postcardinal and renal veins receive innumerable small vessels from the kidneys and a few larger ones traversing the kidney from the body wall. These were not followed or described because no comparable observations are available for other species. With the double injection of vein and ureters, the entire kidney in these specimens was permeated with latex, indicating the extent of the vascular system within.

SARDA

GENERIC CHARACTERS OF THE SKELETON

Cranium

Lateral View

Sarda can be positively identified in this view by one unique character. There is a deep rimmed, crater-like depression in the basioccipital, adjacent to the point where that abuts against the first vertebra, and directly ventral to the projecting margin of the exoccipital where that joins the overhanging margin of the opisthotic. This character is sufficient to separate *Sarda* from any species of the Plecostei.

Dorsal View

Sarda is separable from all species of the Plecostei, except *Auxis*, by the absence of the characteristic paired triangular holes in the posterior margins of the frontals. Small irregular holes are often present in the bonito but these cannot be confused with the large apertures in the tunas. *Sarda* can be readily distinguished from *Auxis* by a large number of characters (see *Auxis*), one of which is the shape of the ethmoid. This is diamond-shaped in *Auxis*, whereas in *Sarda* it is concave anteriorly with a slight median protrusion.

Ventral View

Innumerable differences separate *Sarda* from all species of Plecostei. The absence of the deep recess posterior to the prootic, alone, furnishes a positive diagnosis. It should be emphasized that there is actually a shallow saucer-like depression in this area in *Sarda*, but this in no sense is comparable, nor could it be mistaken for the corresponding recess in the Plecostei. In the latter the depth of this recess is in the magnitude of its length.

A valuable corroboratory character is the anterior extent and shape of the ethmoid in this view. It differs unmistakably from all the Katsuwonidae in which it does not approach the anterior tip of the vomer, and approaches the condition in the Thunnidae, resembling most *N. macropterus* in which the margin reaches almost to the tip of the vomer. From the latter it differs, and can be generally distinguished by the shape of the anterior margin. This is illustrated in Figures 34 and 35.

Vertebral Column

The vertebral column of *Sarda* resembles that of the Thunnidae rather than that of the Katsuwonidae, since the haemal processes do not fuse to form a pedicle. *Sarda*, with 45 (44-46) vertebrae, can easily be distinguished from the Thunnidae which have 39 vertebrae.

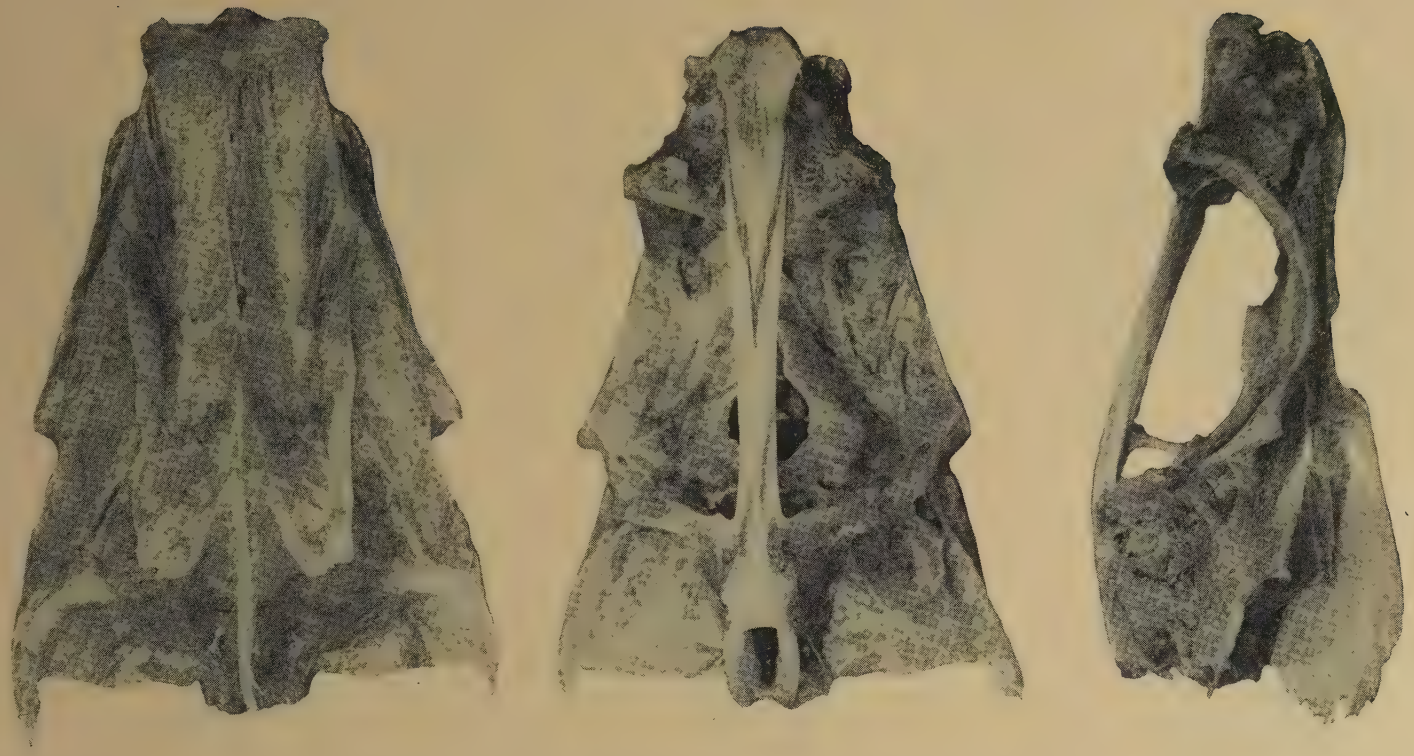

FIGURE 34. Skull of *Sarda lineolata:* dorsal, ventral, and lateral views

FIGURE 35. Skull of *Sarda velox*: dorsal, ventral, and lateral views

SPECIFIC DIFFERENCES IN THE SKELETON

The skeletons of *S. velox* and *S. lineolata* are extremely similar. Although there are numerous minor differences, almost all of them are relative and only a few will enable a positive identification. In the following description only those elements are discussed which suggest differences. Many of the relative differences observed were subsequently eliminated because measurements indicated that they were biometrical in nature, and differed by amounts that had only statistical significance. The limited amount of material and the time available precluded a more thorough study.

With one possible exception the cranium of these two species is individually indistinguishable. Differences observed in a comparison of a single specimen of each disappeared when the comparison was extended to other specimens. However the basisphenoid in *lineolata* is generally a narrow bone only slightly expanded at its lower portion, where it is firmly anchylosed to the parasphenoid. In *S. velox* the basisphenoid is greatly expanded at its lower extremity and it is apparently only loosely attached to the parasphenoid. In the three available specimens the basisphenoid became detached in the cleaning of the cranium, despite the fact that after the condition had been noted in the first, exceptional care was taken with the second and third specimens. Although in occasional specimens (one out of six) of *S. lineolata* the shape of the basisphenoid approaches that of *S. velox,* the usual difference in shape, plus the fact that this bone is never separable (six specimens) in cleaned crania of *lineolata*, whereas it invariably becomes detached in *S. velox*, amounts to a positive diagnostic character.

The vertebral column of an individual can be specifically identified. There were 45 vertebrae, counting the hypural plate, in all (three) of the Galapagos specimens. In nine specimens of *S. lineolata* one had 44 vertebrae, seven had 45 and one had 46. In *S. velox* there were 24 precaudal vertebrae in all three specimens, and therefore 21 caudal vertebrae. In *S. lineolata* there were eight specimens with 23 precaudal and one with 24 precaudal vertebrae. In making this count, precaudal vertebrae were defined as those without the elongated haemal spine. In transitional cases the first caudal vertebra was considered as that one on which the spine was relatively and appreciably longer than those in preceding vertebrae, even though this spine was not as long as succeeding ones.

The haemapophyses turn distinctly ventral-ward on the 10th vertebra in both species. In one specimen only (*velox*) they turned down first on the ninth vertebra. In *S. velox* this first ventrally projecting haemapophysis on each side projects forward as do the immediately succeeding ones, whereas in *S. lineolata* it projects—in almost all specimens—backwards. This is one of the more useful indicative characters of the skeleton. It is not, however, diagnostic, because exceptions occur.

Of the three Galapagos specimens, the first completed haemal arch occurred on the 13th vertebra in one, on the 14th vertebra in the second,

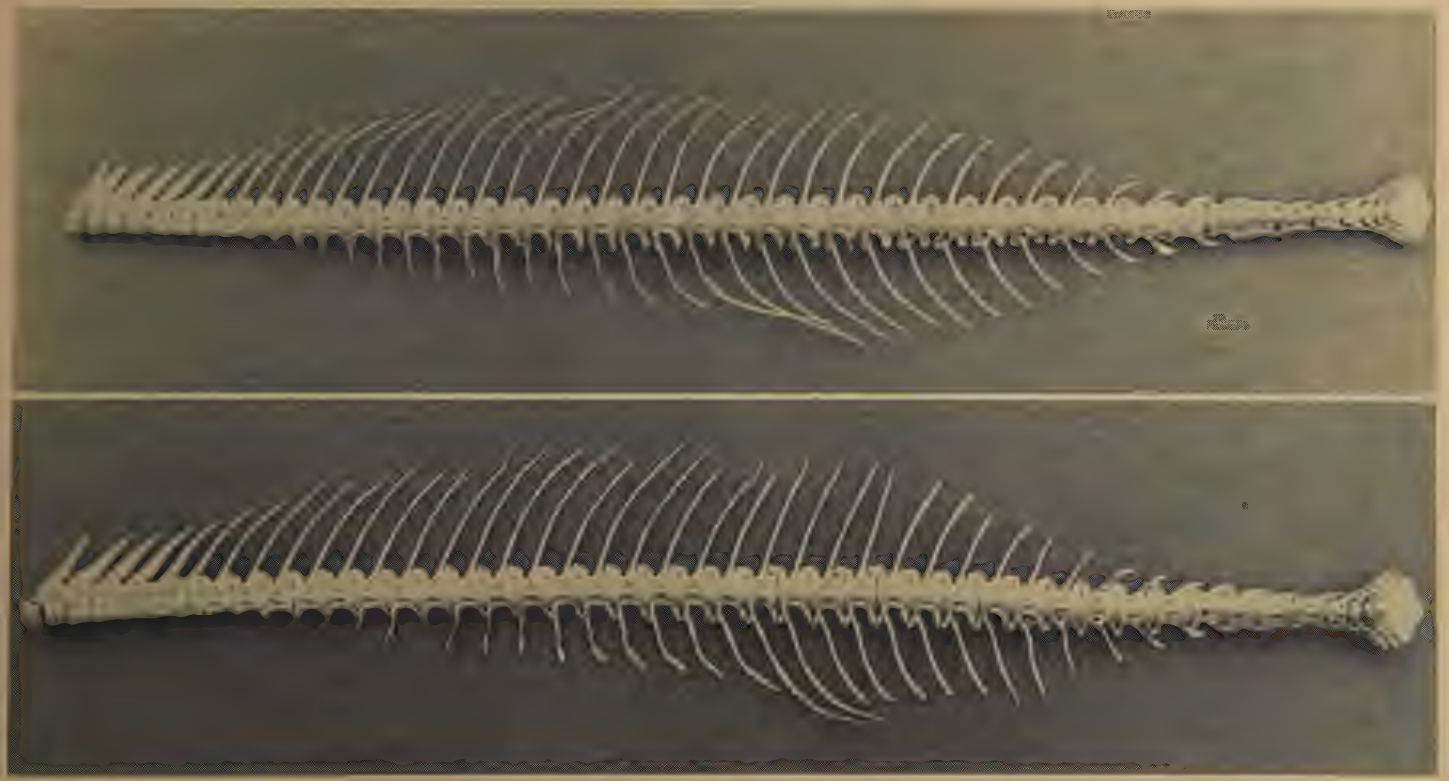

FIGURE 35. Lateral view of the vertebral column of *S. lineolata* (top) and *S* [illegible] (bottom). The first neural spine is missing on the latter.

and on the 15th in the third. In *S. lineolata* the location of this structure in nine specimens was:

12th vertebra—2
13th vertebra—6
14th vertebra—1

The difference is therefore indicative and biometrical.

A subtle though constant and diagnostically valuable difference distinguishes the verterbral column of *velox* from that of *lineolata*. It concerns the minor ventral processes of the central vertebrae. In *lineolata* the inferior zygopophyses projecting ventrally at the posterior end of each vertebra are broad and blunt and point ventrally. Between them and the small spur that projects from the contiguous proximal portion of the next haemapophysis there is rarely any connection and the two are separated by an appreciable space. In *velox* these inferior zygopophyses are finer, distally pointed and they arch posteriorly so that they approximate or abut against the adjacent spur on the haemapophysis, which incidentally, is more developed. While there is considerable variation in individual vertebrae, the aggregate appearance is sufficiently great to identify any and every specimen. Hence this can be considered as a positive diagnostic character and a specific difference.

Of the individual bones the hyomandibular was one of the few that differed positively. In both species a spine-like projection extends posteriorly from the center condyle, as in the Katsuwonidae. In *velox* this spine forms with the major axis of the bone an angle that is 90° or less, whereas in *lineolata* the angle invariably exceeds 90°. With the bone in its normal position and with the major axis vertical, this spine in *lineolata* points upwards, whereas in *velox* it slants downward. This was invariable in all available material, the extent of which was three specimens of *velox* and four of *lineolata*. To this limited extent the character may be considered diagnostic.

FIGURE 37. Hyomandibular: *S. lineolata*, left, and *S. velox*, right

Another characteristic of this bone, when more extensively investigated, may serve to differentiate the two species. In the three specimens of *velox* the ridge of bone margining the groove into which the preopercle abuts is continued dorsally as a weak spine. While this is true also of *S. lineolata* this spine is longer in *S. velox*. When this bone is placed flat with the internal side up and viewed from above, the spine could be seen projecting beyond the center condyle in all specimens of

FIGURE 38. Clavicle: In this figure the arrangement was inadvertently reversed, and *S. velox* is to the left and *S. lineolata* is on the right. Note the difference in the shape of the expanded dorsal portion.

S. velox, whereas in *S. lineolata* it could not be so seen. The length of this spine however, is variable, and a larger series of specimens might provide exceptions to this rule.

A second positive difference observed occurred in the clavicle, Figure 38. In *S. velox* the posteriorly projecting plate at the head of the clavicle has approximately parallel margins with the result that its width throughout its extent is approximately equal and the distal end is bluntly rounded. In *S. lineolata* the dorsal margin of this plate is angled at its mid-length, and as a result the width is obviously greatest at this point and the distal portion is tapered. This was true of the six specimens examined. In every case a positive identification of the species could be made from this bone alone.

A third potential positive difference was found in the tongue. Unfortunately the glossohyal was lost in all but two specimens of each species, but of these four fish the species could be told in all cases from this bone alone. In *S. velox* the tongue is narrow and tapered with the greatest width at the mid-length. Moreover the distal end is straight. In *S. lineolata* this bone is relatively broad, its greatest width being at its distal end, which is distinctly rounded. The ratio of width to length was 1.8 and 1.9 in *S. lineolata*, compared with 2.4 and 2.5 in *S. velox*. Moreover there is a short longitudinal depression on the ventral face of the proximal portion in *S. lineolata* which is lacking in *S. velox*. If these observations are confirmed in other specimens, the several characteristics of this bone could be considered diagnostic.

FIGURE 39. Glossohyal: *S. lineolata*, left; *S. velox*, right. The two serrations on the right edge of the former bone are artifacts caused by an error in blocking the negative.

The differences in the size and number of teeth have been mentioned. Although relative, the visual difference (Figure 40) is conspicuous, and offers a convenient means of identification.

The opercle of the two species differs in outline, but not invariably. The ventroposterior corner of this bone tends to be produced into a blunt process in *S. lineolata*, whereas in *S. velox* the posterior margin is straight. This is an indicative but not a positive difference, because of overlapping variation.

Another indicative difference exists in the pterygoid (not illustrated). The two axes of this "T" shaped bone are more rectangular in *S. lineolata*, whereas in *S. velox* the two axes are obtuse. Although this difference is relative the appearance of the bone is different in the two

FIGURE 40. The teeth on lower jaw: *S. lineolata,* above, and *S. velox,* below.

species. The vertical plate or base is definitely pointed and and angular at both extremities in *S. lineolata,* whereas in *S. velox* the upper or dorsal portion is terminally rounded. This observation included three specimens of *velox* and four of *lineolata.*

Although no difference was noted in the shape of the palatine bones, the bone carries a larger number of teeth in *S. lineolata.* There were from 15 to 18 such teeth in this species, and only 8 to 11 in *S. velox.* It is possible, however, that the number is a function of size. As only three specimens of *velox* and two of *lineolata* were examined, this observation is not conclusive.

The articular bone is different in appearance. In *S. lineolata* the dorsally projecting spine or process is larger and more prominent than in *S. velox* and the origin of its posterior margin is more angular. In *S. velox* the dorsal margin of the articular bone sweeps anteriorly in a smooth curve to the peak of this dorsal process and thus does not present an angular appearance. This difference is obviously relative.

A final positive difference was observed in the auxiliary (or supra-) maxillary bone, covering the dorsal, distal margin of the maxillary. This small bone was much narrower in relation to its length in *S. velox* than in *S. lineolata.* The ratio of width to length was 4.1 to 4.4 in *velox,* and 3.0 to 3.1 in *lineolata* in the three specimens examined of each species. It is the difference in the shape of this bone that causes the difference in the external appearance of the maxillary.

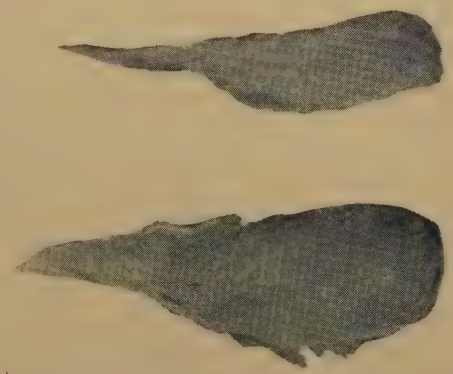

FIGURE 41. Auxiliary maxillary bone: *S. velox,* above, and *S. lineolata,* below.

Although one could make a positive identification of the species by any of the above structures, the most practical diagnostic skeletal structures are the jaw teeth, the gill rakers and gill teeth, and the shape of the distal portion of the maxillary.

A COMPARISON OF THE SPECIES

Anatomically, the two bonitos described are fundamentally alike and differ only in detail. The differences, though minor, are constant and justify the specific separation of the two forms. As the differences are

slight, it sometimes requires consideration of two or more characters to make a positive identification of a specimen. However, a positive identification can be made in every case by reference to diagnostic characters and this identification confirmed by reference to corroboratory characters.

Externally, the pattern of dorsal markings supplies an indicative, though not a positive, means of identification. In most specimens of *lineolata* the 8 to 10 black dorsal stripes are oblique, whereas in *velox* the six to eight stripes are horizontal. This is a corroboratory rather than a diagnostic character because variation is excessive and overlapping.

The shape of the distal portion of the maxillary will positively identify the vast majority of specimens. The extent of overlapping variation is extremely slight and for all practical purposes this can be considered as a diagnostic character. In *lineolata* the terminal portion of the maxillary (plus the auxiliary maxillary) is as wide as long and almost circular, whereas in *velox* it is shaped as in a narrow, elongated, oblique "U".

The count and structure of the gill rakers is diagnostic. In *lineolata* the count of functional rakers on the first arch is 7 to 8 + 1 + 11 to 18 = 20 to 27, whereas in *velox* it is 2 to 3 + 1 + 5 to 8 = 8 to 11, with an increased total count of 3 or 4 if mere rudiments are included. This count is one of the most satisfactory means of identifying the species. In *lineolata* there is a complete and regular set of short posterior rakers—or gill teeth—on the first arch, while in *velox* there are at most a few rudimentary gill teeth on the upper limb and at the angle of this arch.

The structure and number of teeth in the lower jaw affords an additional diagnostic character. In *lineolata* the teeth, though large, are smaller and less regular than in *velox*, and there are approximately 20 on each side. In *velox* these teeth are considerably larger and more regular, and there are normally about 12 on each side. This association of external characters should suffice for a positive identification of any specimen of either species.

Such an identification is confirmed by a consideration of the corroboratory external characters. Included in these are the proportional measurements which the writer does not consider as diagnostic because the range in described proportions is inevitably increased by more extensive observations. All proportional measurements are shown graphically as ratios in Figure 42.

S. velox and *S. lineolata* differ principally in the fact that the head of *velox* is proportionately longer; the ventral fins and the anal fin are inserted more posteriorly in *velox*; in relation to both body and head length, the eye in *velox* is both larger and more posteriorly located than in *lineolata*.

Internally, a number of characters, individually or collectively, will afford a positive identification without regard to external characters. The skeletal differences offer the most satisfactory diagnosis. As these are discussed and summarized in the preceding section it will not be necessary to duplicate that discription. Differences in the viscera and in the vascular systems are, in this instance, of no value in species separation.

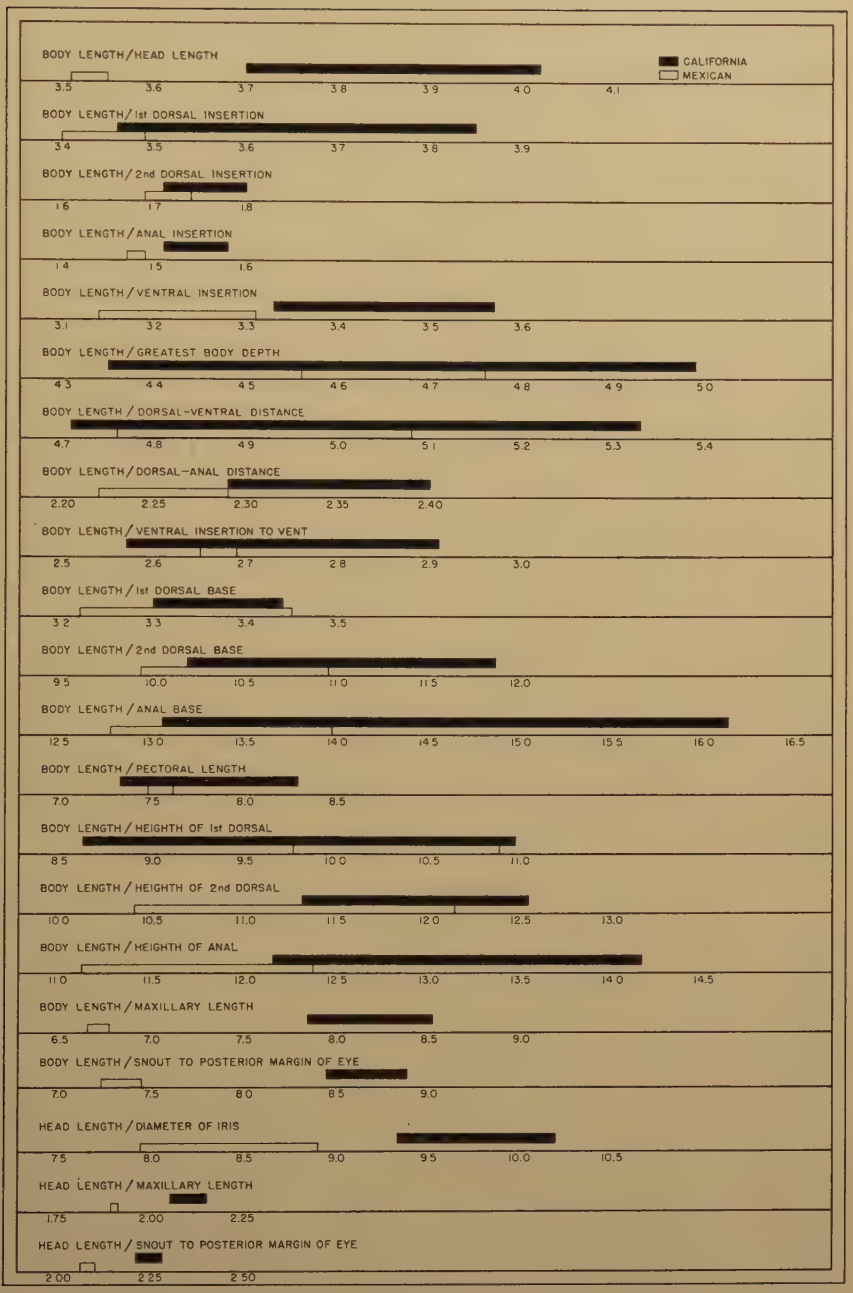
CALIFORNIA
MEXICAN
BODY LENGTH/HEAD LENGTH
3.5 3.6 3.7 3.8 3.9 4.0 4.1
BODY LENGTH/1st DORSAL INSERTION
3.4 3.5 3.6 3.7 3.8 3.9
BODY LENGTH/2nd DORSAL INSERTION
1.6 1.7 1.8
BODY LENGTH/ANAL INSERTION
1.4 1.5 1.6
BODY LENGTH/VENTRAL INSERTION
3.1 3.2 3.3 3.4 3.5 3.6
BODY LENGTH/GREATEST BODY DEPTH
4.3 4.4 4.5 4.6 4.7 4.8 4.9 5.0
BODY LENGTH/DORSAL-VENTRAL DISTANCE
4.7 4.8 4.9 5.0 5.1 5.2 5.3 5.4
BODY LENGTH/DORSAL-ANAL DISTANCE
2.20 2.25 2.30 2.35 2.40
BODY LENGTH/VENTRAL INSERTION TO VENT
2.5 2.6 2.7 2.8 2.9 3.0
BODY LENGTH/1st DORSAL BASE
3.2 3.3 3.4 3.5
BODY LENGTH/2nd DORSAL BASE
9.5 10.0 10.5 11.0 11.5 12.0
BODY LENGTH/ANAL BASE
12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0 16.5
BODY LENGTH/PECTORAL LENGTH
7.0 7.5 8.0 8.5
BODY LENGTH/HEIGHTH OF 1st DORSAL
8.5 9.0 9.5 10.0 10.5 11.0
BODY LENGTH/HEIGHTH OF 2nd DORSAL
10.0 10.5 11.0 11.5 12.0 12.5 13.0
BODY LENGTH/HEIGHTH OF ANAL
11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5
BODY LENGTH/MAXILLARY LENGTH
6.5 7.0 7.5 8.0 8.5 9.0
BODY LENGTH/SNOUT TO POSTERIOR MARGIN OF EYE
7.0 7.5 8.0 8.5 9.0
HEAD LENGTH/DIAMETER OF IRIS
7.5 8.0 8.5 9.0 9.5 10.0 10.5
HEAD LENGTH/MAXILLARY LENGTH
1.75 2.00 2.25
HEAD LENGTH/SNOUT TO POSTERIOR MARGIN OF EYE
2.00 2.25 2.50

FIGURE 42. *Sarda:* The range in the ratios of the respective measurements to either body length or head length

Of the skeletal elements the skull can be identified in most cases by the shape and attachment of the basisphenoid. The vertebral columns can be positively identified by the aggregate of characters discussed in the preceding section. Of these the shape and appearance of the inferior zygopophyses are most indicative. Of the individual bones a positive identification can be based upon the hyomandibular, the clavicle, the glossohyal and the auxiliary maxillary bone. The remaining corroboratory characters will inevitably fit into this identification.

On the basis of the above differences any and every representative of either species can be positively identified. The two species are unquestionably distinct. The correct nomenclature, however, is debatable. The writer has used, provisionally and uncritically, the names in common usage, without conviction of their validity.

There is a striking agreement in the present description of *S. velox* with Kishinouye's description of *S. orientalis*. The vast majority of characters adequately described agree in detail. As far as such a comparison can be made, the only differences noted are in the following structures. Kishinouye gives the gill raker count as $4 + 9 = 13$, whereas *S. velox* is credited herein with 2 to $3 + 1 + 5$ to $8 = 8$ to 11. The latter count, however, ignores mere protuberances (see page 49) and if these are included *velox* becomes comparable with *orientalis*. Moreover, Meek and Hildebrand (1923), in their original description of *velox*, give a count of nine gill rakers on the lower limb of their specimen, and Walford (1936) lists the count of gill rakers on the lower limb as seven or eight. In view of this, one can assume no difference between *velox* and *orientalis*.

There are three differences that need further investigation before positive conclusions can be drawn. Kishinouye states that there are $25 + 20$ vertebrae in *S. orientalis*. The three specimens of *S. velox* examined all had $24 + 21$ vertebrae. Whether or not this difference is substantiated by future observations, it is hardly sufficient, of itself, to warrant a specific separation.

In *S. velox* the right and left lobes of the liver are both attenuated and the right lobe is only slightly longer than the left. In Kishinouye's illustration, *S. orientalis* is portrayed with a left lobe that is roughly half the length of the right. Although this difference is relative, it would bear further investigation.

Kishinouye's illustration of *S. orientalis* shows a preoperculum with a relatively straight, vertical posterior margin and with an angular posteroventral corner. In *S. velox*, according to present findings, . . . "The posterior margin of the preoperculum is generally more rounded than that of *lineolata*, with the result that the posteroventral outline is less angular." The illustration accompanying the original description by Meek and Hildebrand accords with this description of *velox*, and the photograph of *velox* reproduced by Walford (1937) shows a smoothly rounded preopercular margin. However, this character is quite variable and somewhat unsatisfactory, and though an actual difference exists between *velox* and *orientalis*, this of itself would not justify the separation of the two species. Their validity—or synonomy —should rest upon a subsequent direct comparison of the two varieties.

The validity of *S. lineolata* has been questioned. Hildebrand (1946) expresses the opinion that: "The extent of the corselet in comparison with the length of the pectoral, a character supposedly differentiating *S. chiliensis* and *S. lineolata* . . . is entirely unreliable. Among specimens examined from Peru and elsewhere the demarcation of the corselet, sometimes is indistinct, and it may not be equally distinct or equally long on both sides of the same fish." The present writer is also of this opinion, but has used "*lineolata*" provisionally pending a detailed and direct comparison of specimens from California and from Peru. Such a comparison of *lineolata* with *chiliensis*, and of *velox* with *orientalis* would eliminate much of the confusion in the existing literature.

FIGURE 43. Frigate mackerel, *Auxis thazard*. Taken October, 1949, Morgan Bank, Baja California. *(Photo by Vernon M. Haden, San Pedro.)*

FRIGATE MACKEREL (*Auxis thazard*)

The description of this species is based upon a total of six specimens. Of these, five were subjected to a complete dissection. The sixth was superficially examined. Specimens No. 1 and 2 were caught early in 1952 off Cape San Lucas, Baja California. Specimens No. 3, 4, 5, and 6 were taken at or in the vicinity of Culpepper Island, in the Galapagos group, either in December 1952 or January 1953. These specimens ranged in body length from 309 mm. to 355 mm., and all measurements or distances mentioned in the text relate to fish of this size.

EXTERNAL CHARACTERS

The frigate mackerel can be separated from all other members of the family Katsuwonidae in which it belongs, by the divided dorsal fin. It is the only member of the two related families, Katsuwonidae and Thunnidae with this character. In this respect it superficially resembles in appearance the Pacific mackerel.

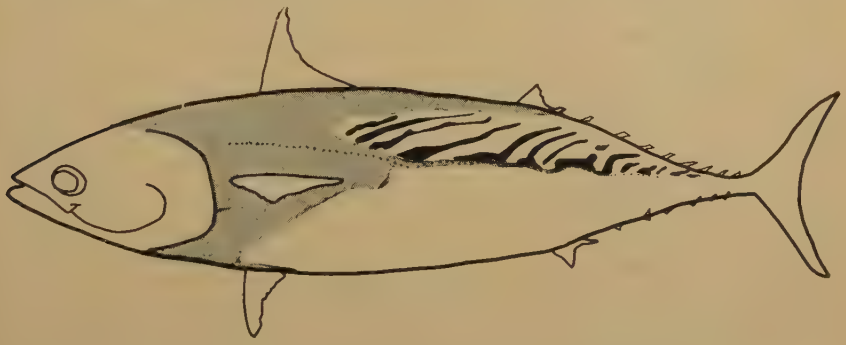

FIGURE 44. Frigate mackerel: This sketch illustrates the markings, the course of the lateral line, the shape and the extent of the corselet

The markings in *Auxis* resemble those of *E. alletteratus*. They consist of narrow black wavy, oblique lines sloping upward and posteriorly from the lateral line. There are about 14 such bars. As in *Euthynnus* they are quite variable, and the two sides of a fish may differ appreciably. In some specimens the lines are horizontal, and such horizontal lines give off oblique wavy branches. Both the horizontal and oblique lines may be broken into segments or spots.

The markings are superimposed upon a blue or indigo background delimited ventrally by the scales along the lateral line and dorsally by a mid-dorsal scaled wedge of black, tapering from the head to the vicinity of the sixth or seventh dorsal finlet. This strip of black is relatively broad, with the result that the area of blue showing the markings is quite narrow. Anteriorly the plaque of blue extends slightly beyond the tip of the pectoral fin. The belly of the fish is silvery, without spots or markings. There is an irregular elongated black spot at the upper termination of the gill cover, and another such small spot on the ventroposterior margin of the eye. Figure 44 illustrates the mark-

ings in one of the specimens dissected, while Figure 43 is from a photograph of a specimen not used in this study.

The lateral line lacks a pronounced arch over the pectoral fin. It is obscure and extremely difficult to follow in this region. There appears to be a slight upward slope to the line, reaching a maximum above the mid-length of the pectoral, and then an equally slight downward slope. The wave thus formed is negligible. Posteriorly the line may be relatively straight or quite wavy. As a rule it is quite straight between the tip of the pectoral and the second dorsal insertion. From there posteriorly there are typically two conspicuous undulations. One consists of a dip below the second dorsal base and the other a dip below the second dorsal finlet. While this appears to be typical, it is by no means invariable and there may be several undulations below the finlets. In one specimen there was an appreciable dip roughly midway between the end of the first dorsal base and the second dorsal insertion. The lateral line is accurately depicted in Figure 44. The corselet in this species is short. There is a narrow ribbon of scales along the lateral line and a bulge or slight posterior projection ventral to this on the level of the pectoral fin. This ventral bulge, illustrated in Figure 44, extended in these specimens roughly two centimeters posterior to the tip of the pectoral. Related to the length of the pectoral, this ventral bulge extends beyond the tip of the pectoral, a distance equal to 0.4 to 0.5 the pectoral length. Directly above the end of this ventral projection the ribbon of scales about the lateral line measured from six to eight mm. in width. This ribbon tapers rapidly and within two or three centimeters posterior to this, measures only two or three mm. in width. Below the second dorsal insertion the width is a millimeter or less.

The plaque of scales surrounding the ventral fins extends posteriorly a distance of about one cm. from the tip of the ventral fins, ranging from nine to fourteen mm. in the several specimens.

The two dorsal fins are separated by a distance that exceeds the length of the first dorsal base (see Table 8). The latter was taken as the distance between the first and last ray. The first dorsal fin is high, being about one-tenth the body length (0.11 to 0.12). Its margin is sharply concave, with the first ray the longest. There were 11 rays in this fin in all specimens. Fitch and Roedel in a series of 57 specimens (unpublished data) record a range from 9 to 11, with 11 overwhelmingly preponderant. The first dorsal is inserted slightly posterior to the ventral insertion, and the latter is again slightly posterior to the pectoral insertion.

The second dorsal is low, being about half the height of the first dorsal. There were from 10 to 12 rays in this fin, but this count is somewhat questionable. In the above series, Fitch and Roedel record 12 as the modal count, with a range from 11 to 13. There are normally eight dorsal finlets, although in one specimen there were nine. The anal fin is inserted on a vertical that passes between the end of the second dorsal base and the insertion of the first dorsal finlet. The anal fin is low, being comparable in height with the second dorsal. The recorded ray count, from 9 to 12, is entirely unreliable. This fin and the second dorsal were dried and hardened, and only an approximate count was made. Fitch and Roedel found a modal count of 13 in the anal fin, with a range from 11 to 14.

The posterior margin of the gill cover is roughly vertical, approximately straight or slightly convex posteriorly, and in no way distinctive. The lower posterior corner is angular. The preopercular margin is sharply rounded, as in *Euthynnus*. The maxillary barely reaches in some specimens, and fails to reach in the majority, the vertical through the middle of the eye. The distal end of the maxillary, with the auxiliary maxillary bone, is exposed in this genus, as in all the Katsuwonidae, and not concealed as in *Pneumatophorus*. The eye is covered anteriorly with a vertical membrane extending slightly over the iris. The jaw teeth are small and weak, forming an edge which to the touch feels like a coarse file. There are no detectable teeth on the vomer or palatines. The dorsally projecting lateral cartilaginous ridges on the tongue, characteristic of the Plecostei, are moderately developed in *Auxis*. The interpelvic process is diagnostic of the genus. It is not divided, but forms a long single acorn-shaped structure reaching to, or almost to, the tip of the ventral fins (Figure 45). The vent is an elongated oval aperture measuring in these specimens eight or nine mm. in length.

The caudal peduncle is noticeably flattened. While there is no cartilaginous keel as in the Thunnidae, the presence of the osseous keels is more conspicuous than in *Euthynnus*. There are, on the base of the caudal fin, two slight and inconspicuous ridges on each side. These ridges run roughly parallel, one above and one below the mid-line and appear to coincide with the attachment of the caudal rays. (See Herald 1951.)

FIGURE 45. Frigate mackerel: Interpelvic process

Gill rakers are long and numerous on the first arch. There is a raker at the angle of this arch, and this raker has both a dorsally and a ventrally projecting base. The dorsal base is very short, and is easily overlooked, while the ventral base of this raker, anchored to the lower limb of the arch, is extremely long. This is characteristic of the species, or probably the genus.

A peculiarity of this raker, observed in all but one specimen, was the shape of its proximal edge. The mesial margin at this point was twisted through an angle of roughly 45 degrees to form an elongated "S". The raker count [3] was 10 (10-11) + 1 + 33 (31-34) = 45 (42-45), (see Table 9). On the second and third arch gill rakers are entirely absent except at the angle of the arch. Here there are two or three short rudimentary rakers. In addition to these there are on the upper arm of the third arch, scattered, stubby rakers with a greater concentration and regularity at the upper extremity of this arch. On the fourth arch there is a complete set of short rudimentary rakers over the entire extent of the upper arch and scattered or even numerous rakers on the lower arch. This was true of all specimens.

There are gill teeth or posterior rakers on all arches. Those on the first arch are perhaps the longest, but those on the second and third

[3] This result is supported by additional data supplied by J. E. Fitch. In a collection of 58 specimens of this species Fitch found a modal gill raker count of 10-1-34, and a total modal count of 45. Variation was from 9 to 12 on the upper limb and from 30 to 36 on the lower limb, with one additional raker consistently at the angle of the arch.

arches are nearly as well developed. The gill teeth on the fourth arch are short. Those of the third and fourth arches have bristle-like spines or villous teeth attached to each, as in the Pacific mackerel. The total count of gill teeth on the first arch ranged from 31 to 34, with 9 to 11 teeth on the upper arm and 21 to 23 on the lower arm. This count excludes one or two mere protuberances on the arch of occasional fish, which could be interpreted as additional gill teeth. The same remark applies to a less extent to the gill raker count. Proportional measurements and meristic counts are tabulated in Tables 8 and 9.

TABLE 8

Frigate Mackerel: The Measurements Made Upon Five Specimens, and the Range in the Resulting Ratios, of Which Body Length Is the Numerator in Each Case Except Those Indicated by an Asterisk. In the Latter the Head Length Becomes the Numerator.

	Fish number					
	No. 2	No. 3	No. 4	No. 5	No. 6	Ratios
Body length	339	354	ca355	346	309	
Head length	95	95.5	--	93.5	83.5	3.57– 3.71
1st dorsal insertion	113	112	--	109.5	99	3.00– 3.16
2d dorsal insertion	215.5	223	--	219	195	1.57– 1.59
Anal insertion	231.5	237	--	239	209	1.45– 1.49
Ventral insertion	105.5	105.5	--	102	91	3.21– 3.40
Greatest body depth	75	82	--	81.5	ca 70	4.25– 4.52
Greatest body width	57	59	--	ca 54	52	5.94– 6.00
Dorsal-ventral distance	75	78	--	77	65	4.49– 4.75
Dorsal-anal distance	144.5	152	--	150	ca135	2.31– 2.35
Ventral insertion to vent	123	126.5	--	132	116	2.62– 2.80
Length of 1st dorsal base	52	54	54	53	--	6.52– 6.56
Length of 2d dorsal base	18	ca 22.5	--	20	16.5	17.30–18.83
Length of anal base	17	22.5	--	19	17.5	15.73–19.94
Pectoral length	48.5	47	--	48	43	6.99– 7.53
Spread of caudal	--	81	--	79	70+	4.37– 4.38
Height of 1st dorsal	39	39	38	ca 38	ca 29	8.69– 9.08
Height of 2d dorsal	ca 16	ca 17	--	ca 17	16	19.31–
Height of anal	ca 16.5	17	--	17	ca 15	20.35–20.82
Dorsal interspace†	53.5	62.5	ca 56	62	ca 66	5.58– 6.34
Diameter of iris	ca 14	14.5	--	13.5	12.5	*6.59– 6.93
Maxillary length	30	30	--	28.5	26	*3.17– 3.28
Snout to posterior margin of eye	--	36	--	35	--	*2.65– 2.67

† This measurement is the lineal distance between the last spine of the first dorsal fin and the insertion of the second dorsal fin, made with the fins erected.

INTERNAL ANATOMY

Ventral View of the Viscera

The ventral view of the viscera, *in situ*, supplies a positive identification of the genus, if not the species. The extent and location of the right lobe of the liver and the presence of conspicuous hepatic veins on the ventral surface of all lobes separates *Auxis* from all other genera except *Euthynnus*. From *Euthynnus*, *Auxis* is distinguished by the fact that the intestine is invariably on the left side of the body cavity and the gall bladder is conspicuous in this view. In occasional specimens the gall bladder may be empty and flesh-colored, in which case it is plainly discernible although not conspicuous. This view was consistent in all specimens examined and no exceptions were encountered.

TABLE 9

Frigate Mackerel: Meristic Counts Made Upon Five Specimens

	Fish number				
	No. 2	No. 3	No. 4	No. 5	No. 6
1st dorsal rays	11	11	11	11	11?
2d dorsal rays	10	11?	12?	12	11
Dorsal finlets	8	8	9	8	8
Anal rays	11?	9 or 10?	12? or 11	12	11
Anal finlets	7	7	7	7	7
Gill rakers:					
Upper limb	10	11	10	10	10
Angle	--	1	1	1	1
Lower limb	35	33	31	33	33
Total count	45	45	42	44	44

Caecal Mass

This is a triangular mass lying at the anterior end of the body cavity on the left side. The apex lies on the left side at approximately the mid-length of the body cavity. The anterior apparent base of the triangle is actually "Y"-shaped, with the center lobe of the liver in the throat of the "Y." The two arms of the caecal mass encircle the pyloric region of the alimentary canal, and fuse dorsal to the duodenum. It is in this general region that the majority of the caecal ducts connect with the alimentary canal. There are approximately nine such ducts. In color the caecal mass is yellowish with a pink hue. In texture it is smooth, with a slight granular appearance in most specimens. The enclosed caeca are not superficially apparent.

Liver

The liver of *Auxis* resembles that of *Euthynnus*. The right lobe is extremely long, extending the entire length of the body cavity. The center lobe is short but moderate in extent, while the left lobe is relatively minute. In fact the latter appears frequently more like a lobule from the center lobe rather than a distinct left lobe.

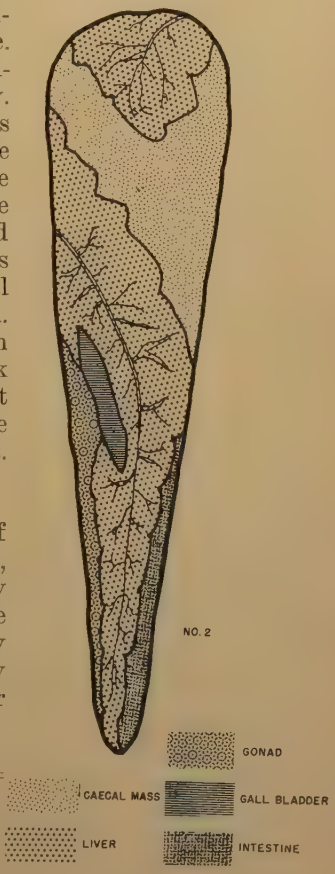

FIGURE 46. Frigate mackerel: Ventral view of the viscera, *in situ*

The liver of *Auxis* can be distinguished from that of any other of the described species by the relative extent of the three lobes, combined with the presence of conspicuous hepatic veins on the exposed ventral surface. The latter character separates *Auxis* and *Euthynnus* from all other genera, while the insignificant left lobe of *Auxis* differentiates this genus from *Euthynnus*, in which the center and left lobes are approximately equal in length and extent. The excised liver is illustrated in Figure 47.

FIGURE 47. Frigate mackerel: Ventral view of the excised liver

The attenuated portion of the right lobe curves from the head of the liver on the right side to the center line and continues mesially, its entire width exposed, to the end of the body cavity. It dominates this view of the viscera. The center lobe, though short, is quite extensive. It lies mesially or on the left side with most of its ventral surface exposed to view. The left lobe is very small and is invariably concealed from view by the caecal mass and duodenum. The outline of the liver is in places diffuse and not sharply defined. Thus the center lobe is adherent to the caecal mass which lies immediately dorsal to it, and the limits of the two organs are sometimes difficult to determine.

Large hepatic veins run in the ventral face of all lobes. These are conspicuous, even without injection. A peculiarity of these vessels is their occasional size. In places the small branches from the main trunk expand into sac-like structures, as illustrated in Figure 47. All hepatic veins are enmeshed with an arterial network as in *Euthynnus*, resulting from the break-up of branches of the coeliac mesenteric artery in the substance of the liver.

Stomach

The long stomach in this species is exceptionally small in diameter, appearing finger-like, with little taper towards the distal end. It is generally entirely concealed in ventral view, beneath the right lobe of the liver or the gonad. In one important respect it differs from all other members of this order. While the pylorus arises normally on the left ventrolateral face of the stomach, its origin is not at the anterior end of the stomach as in other genera, but far more posterior than in any other tuna. It approaches in this respect the condition of the Pacific mackerel in which the pylorus originates near the mid-length of the stomach. In *Auxis* its origin is intermediate in position as illustrated in Figure 48.

Intestine

The duodenum originates in the pylorus on the left side and runs obliquely to the right, anterior extremity of the body cavity, traversing the ventral face of the stomach. It is a greatly expanded thin-walled tube, into which the caecal ducts empty. There are approximately nine of these, eight of which discharge into the posterior face of the duodenum while one empties, as in other genera, into the anterior wall of the duodenum at its juncture with the pylorus. The posterior caecal apertures are distributed over the entire length of the duodenum. There are one or two small ones at the distal end, where the duodenum constricts to form the small intestine, and one immense complex duct at the proximal end. The latter is comparable with the large duct in other tunas connecting with the branching system of ducts in the dorsal face of the caecal mass.

At the anterior end of the body cavity the duodenum constricts and as the small intestine runs directly to the vent, without a fold or convolutions. Approximately at its mid-length there is an abrupt but slight increase in diameter, marking probably the origin of the rectum.

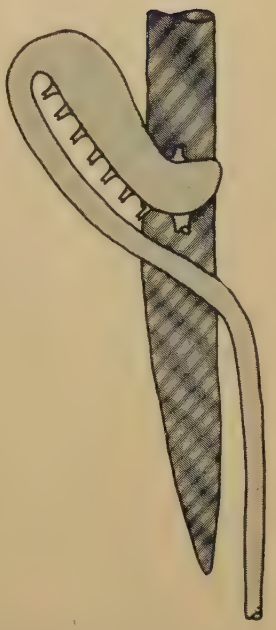

FIGURE 48. Frigate mackerel: The course of the intestine and the origin of the intestinal tract

The intestine parallels the course of the duodenum and thus crosses to the left side of the fish. It is invariably closely associated with the apex of the caecal mass, and from this point posteriorly it lies against the left lateral wall of the body cavity, or against the left gonad. The alimentary canal of *Auxis* is diagnostic of the genus. Lacking a fold of the intestine, it differs from all the Thunnidae. It differs from all other genera of the Katsuwonidae in the location of the pylorus. It is also the only species of the Katsuwonidae in which the intestine runs posteriorly on the left side.

Spleen

This is a moderate, elongated amorphous organ located anteriorly on the right side, enclosed between the wall of the stomach and the dorsal face of the right lobe of the liver. In this position it is entirely hidden in ventral view. The posterior portion of the spleen projects freely into the body cavity and is not rigidly attached to other visceral organs. It extends posteriorly to about the mid-length of the body cavity, or slightly beyond. In color it is characteristically dark red. As the spleen decomposes rapidly it can be studied and described only in relatively fresh specimens. The location of the spleen is, in general, the same in all species of the Katsuwonidae and differs from all species of the Thunnidae.

Gall Bladder

This is a bright green tubular structure attached to the right lobe of the liver. It is located in the right or lateral margin of this lobe in such a manner as to be conspicuous in ventral view of the viscera. The posterior end of the bladder generally projects dorsal to the liver and is therefore concealed, while the anterior end is recessed into a cleft in the lateral margin of the right lobe so that the anterior extremity is generally hidden in ventral view. This cleft is common to *Auxis* and *Euthynnus*. Anteriorly the gall bladder tapers into a bile duct which runs anteriorly adherent to the right lobe of the liver. Its fate was not determined. Within the Katsuwonidae, *Auxis* is the only genus in which the gall bladder appears conspicuously in ventral view of the viscera. To this extent it is diagnostic.

Air Bladder

There is no air bladder in this species.

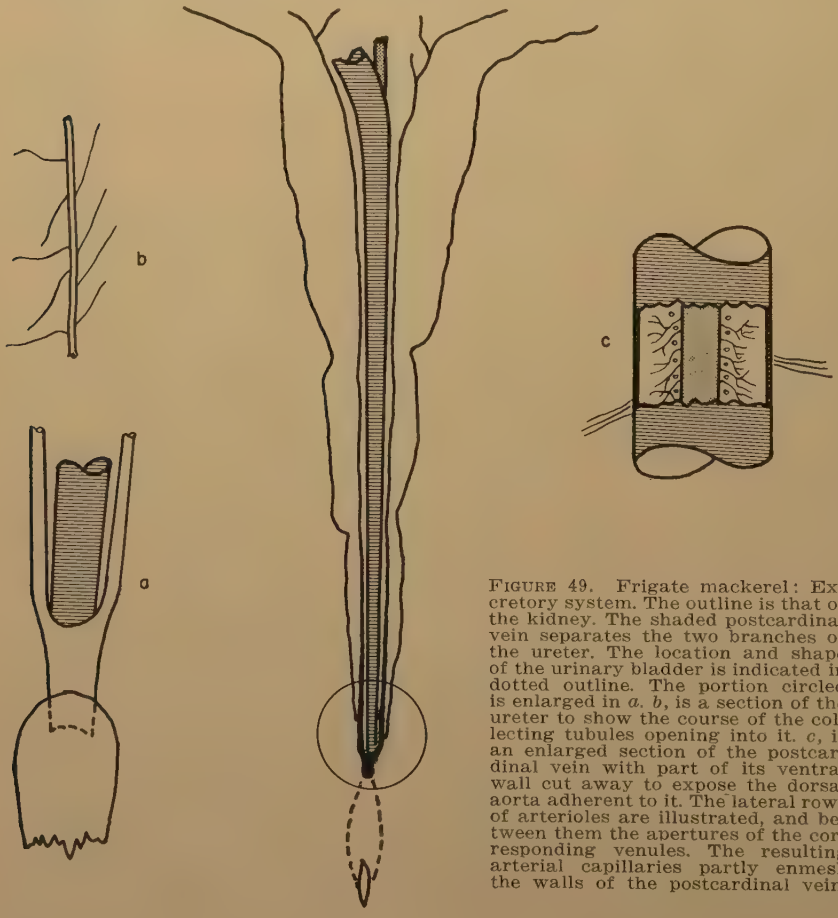

FIGURE 49. Frigate mackerel: Excretory system. The outline is that of the kidney. The shaded postcardinal vein separates the two branches of the ureter. The location and shape of the urinary bladder is indicated in dotted outline. The portion circled is enlarged in *a*. *b*, is a section of the ureter to show the course of the collecting tubules opening into it. *c*, is an enlarged section of the postcardinal vein with part of its ventral wall cut away to expose the dorsal aorta adherent to it. The lateral rows of arterioles are illustrated, and between them the apertures of the corresponding venules. The resulting arterial capillaries partly enmesh the walls of the postcardinal vein.

Excretory System

Kidney

In shape, the posterior extension of the kidney resembles that of *Euthynnus*. It is a narrow tongue or wedge of tissue embedded in the median dorsal wall of the body cavity. It extends definitely to within one or two cm. of the vent and is often prolonged beyond this as a thin thread of indeterminate length. Its lateral margins are ill defined. They appear to be relatively straight, but there are suggestions of serrations between the ribs resembling those found in the Pacific mackerel. Such serrations, however, are slightly developed, and are not shown in Figure 49. In the pectoral region the kidney expands laterally and covers most of the lateral body wall, as in other genera of this family. Lying in the mid-dorsal line embedded in the substance of the kidney is the large postcardinal vein which extends, exposed to view, to the posterior extremity of the body cavity and divides (in appearance only) the kidney into two lateral halves.

Ureter

The ureter in *Auxis* resembles that of the Pacific mackerel, but differs from all other species in this order. From its attachment at the urinary bladder the ureter runs as a moderate trunk dorsally and anteriorly and passes immediately through the complex interlaced fibrous sheath lining the dorsal wall of the body cavity. At this point it divides immediately into two branches. The entire length of this common trunk, from bladder to division, varied between five and eight mm. Hence with the exception of this distance, the ureters in *Auxis* are separated throughout their length. This distinguishes *Auxis* from any other member of the order.

The actual fusion of the two branches into a common trunk resembles more a "U" than a "Y". In this respect it is again like the Pacific mackerel. Anterior to this fusion the two branches are separated by the postcardinal vein which at this point is two or three mm. in diameter. At no point do the ureters run in contact with the wall of the postcardinal. Throughout they are separated by a distance of at least one mm. The ureters can be seen anteriorly, running parallel and separated by the postcardinal, to about the mid-length of the body cavity. At this point the postcardinal begins to deflect to the right. While the right ureter continues to parallel the postcardinal, the left ureter continues anteriorly more or less in a straight line, or in a gradual outward curve, thus leaving the postcardinal. As the kidney expands in the pectoral region, the ureters curve laterally and disappear into the lateral kidney mass. Before doing so, each vessel sends a branch anteriorly. Beyond this point the ureters were not followed.

The ureters are small throughout and difficult to inject. Each branch receives numerous small and occasional large collecting tubules from all directions. The tubules from the mesial portion of the kidney run obliquely posteriorly and join the mesial face of the ureter, while tubules from the lateral portion of the kidney mass run transversely or anteriorly to join the lateral face of the ureter.

Urinary Bladder

This is inconspicuous and difficult to locate and discern. It is a thin-walled sack suspended in a membrane from the dorsal wall of the body cavity between the gonads. It is relatively short, measuring not over 20 mm. in any specimen, from external orifice to anterior tip. The ureter joins the bladder at or near its anterior end, but the actual opening of the ureter into the bladder was not seen. The bladder in this species appears to differ from that of other genera of the family, in that it is not directly attached to or embedded in the dorsal wall of the body cavity. As in the Pacific mackerel, the bladder in *Auxis* appears to be suspended from the dorsal wall by a mesentery. Thus the excretory system of *Auxis* provides a positive diagnostic character. The almost completely separated ureters, the posterior exposed extent of the postcardinal vein and the suspension of the urinary bladder differentiate unmistakably this genus from any other in the entire order.

Circulatory System

Anterior Arterial

This system in *Auxis* differs in several respects from any other species investigated. While the same vessels are present the arrangement of these is sufficiently different to distinguish it from other species. Furthermore there is present a pair of vessels not found in any other species and these constitute a positive diagnostic character.

The anterior efferent branchials are extremely long and enclose a smaller angle than found in any other species. The aorta resulting from their fusion continues a greater distance than usual before receiving the posterior efferent branchials. A pair of small vessels found in all other species is in this case more developed and conspicuous. This pair originates in the ventral face of the aorta roughly at the point where the posterior efferent branchials join the aorta. Each vessel of this pair runs laterally with and ventral to the fourth efferent branchial towards the upper extremity of the gill arches. Its fate was not determined. Each vessel of this pair branches and sends one appreciable and two or three smaller vessels anteriorly.

The posterior efferent branchials themselves appear different in *Auxis* from those of other species. This is due to the direction taken by each vessel and the angle enclosed. Whereas in other tunas the angle enclosed between the third and fourth efferent branchials of each side is relatively small, this angle is wide in *Auxis*. Moreover the fourth efferent branchial is approximately perpendicular to the aorta and the third efferent branchial runs anteriorly at an agle of roughly 45° with the aorta.

The character which distinguishes positively this species from all others is the presence of a pair of ventral cutaneous arteries which arise in the aorta just anterior to the cutaneous trunks. This is the only species in which this condition was found. Hence, the genus if not the species, can be positively identified by this character (Figure 50).

The "Y" of the aorta is beneath the extreme anterior end of the second vertebra. The posterior efferent branchials arise usually beneath the posterior half of the third vertebra. The coeliac mesenteric artery arises on the right side beneath the posterior half of the fourth or occa-

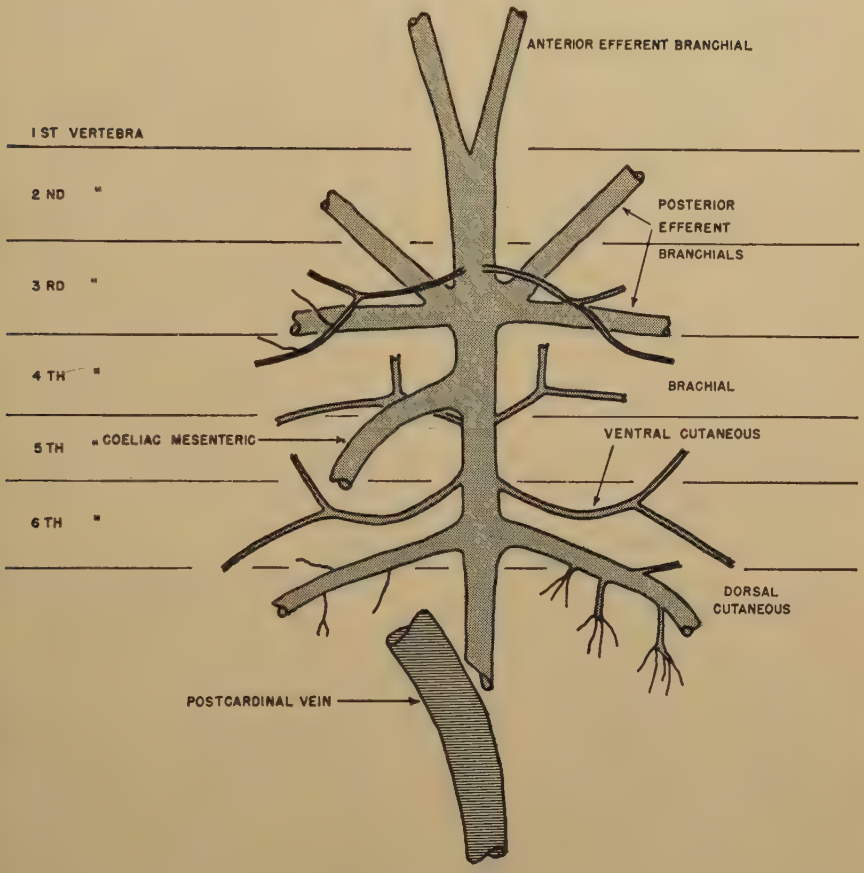

FIGURE 50. Frigate mackerel: Anterior arterial system. The proximal portion of the postcardinal vein is also shown.

sionally beneath the junction of the fourth and fifth vertebrae. The brachials arise just posterior to this, generally beneath the junction of the fourth and fifth vertebrae or occasionally beneath the extreme anterior end of the fifth vertebra. The ventral cutaneous arteries in these specimens arose opposite each other beneath the posterior half of the fifth vertebra or beneath the junction of the fifth and sixth vertebrae. The cutaneous trunks (in this species, the dorsal cutaneous vessels) arose opposite each other in two specimens and staggered in the other two injected specimens. In one of the latter cases the left vessel was anterior to the right, while in the second case the right was anterior to the left. The cutaneous arteries in this species are not perpendicular to the aorta. They curve posteriorly and form with the aorta an angle not exceeding 80°. This was true of all specimens examined. Generally these vessels arise beneath the middle of the sixth vertebra.

Beyond the origin of the cutaneous no major vessels arise. The aorta continues posteriorly little diminished in size in the substance of the kidney. Within a short distance (less than one-half inch) it meets the

postcardinal vein and from this point posteriorly it gives rise on each side to a continuous row of arterioles spaced about a millimeter apart. These arterioles break up immediately into capillary sheets which run predominantly into the substance of the kidney. Anteriorly many, if not most, of these capillary sheets on the right side run into the wall of the postcardinal vein. Posteriorly a few capillaries run similarly but the great majority appear to nourish the kidney. From the point at which the dorsal aorta contacts the postcardinal vein it continues posteriorly adherent to the dorsal wall of the latter throughout the entire length of the body cavity. When the ventral wall of the postcardinal vein is opened the two lateral rows of arterioles can be seen throughout the entire length of the body cavity. While these arterioles become smaller posteriorly with the diminishing aorta they are nonetheless as numerous and as regular throughout. It is characteristic of this genus that the first completed haemal arch is more posteriorly located than in any other, and as a consequence the postcardinal vein with the dorsal aorta adherent is exposed to view as far as the 22d vertebra. This is approximately two vertebrae anterior to the vent which is directly ventral to the 24th vertebra.

Cutaneous

There is in this species a cutaneous system of blood vessels comparable with that of *Euthynnus* but differing from it in several significant ways. In *Auxis* there is no connection between the dorsal branch of the cutaneous artery and the ventral branch. Each has a separate origin in the aorta. Hence, what is described for other species as the trunk of the cutaneous artery is in this case exclusively the dorsal branch. To avoid confusion the two branches are described separately.

The paired dorsal branches of the cutaneous artery arise in the aorta beneath the sixth vertebra. From its origin each branch runs laterally, curving posteriorly, so that each forms with the posterior aorta an angle estimated at 70° to 80°. Each artery runs to the ribs through kidney tissue. In this extent the left branch gives rise to two or three small vessels which immediately break up into a complex system branching throughout the adjacent kidney tissue. On the right side a few capillaries or minute vessels replace these branches. Reaching the ribs the cutaneous artery passes between the third and fourth ribs on each side. This was true of all specimens investigated. At this point each artery gives rise from its anterior face to a small vessel which runs into the deeper musculature, having no connection whatsoever with the ventral cutaneous branch. Beyond the ribs each dorsal cutaneous branch curves posteriorly and passing between the intermuscular bones reaches the surface just dorsal to the pectoral insertion. In the specimens examined the artery passed either between the fourth and fifth intermusculature bones or between the fifth and sixth. These data are approximate because of the difficulty of positively locating the first intermusculature bone. Reaching the surface, the dorsal branch of the cutaneous artery runs in a relatively straight line within the superficial musculature to the caudal region. In no case was a complete injection of the terminal vessels obtained. The artery diminishes in size and with the vein appears to terminate in a branching system beneath the integument in the caudal region (Figure 51).

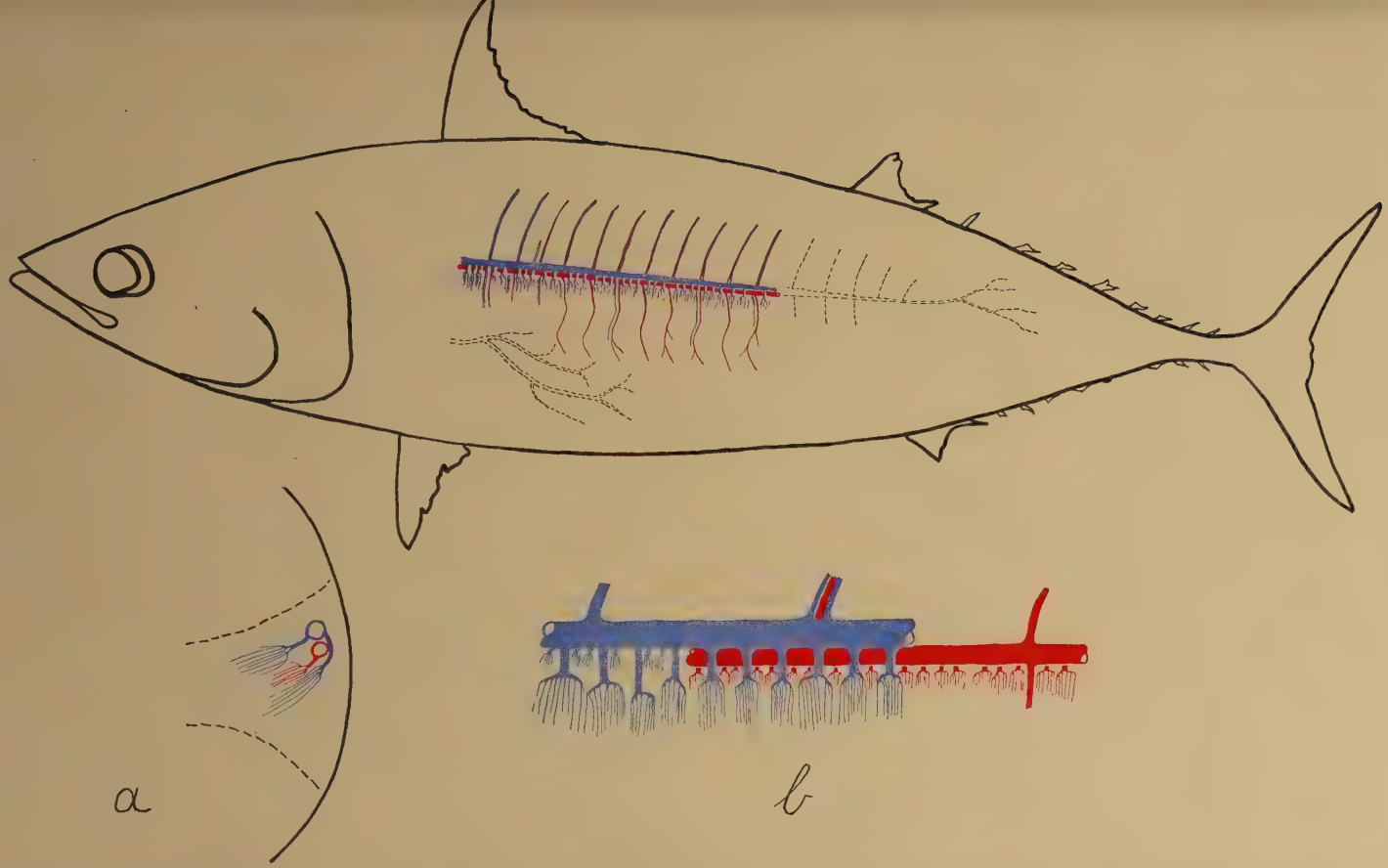

FIGURE 51. Frigate mackerel: Cutaneous system. The dotted, uncolored portion of this system is that part which was seen but not injected. Hence the detailed portrayal of vein and artery is not possible. *a* shows the origin in the dorsal branches of venules and arterioles, while *b* shows the detailed appearance of the dorsal branches and their tributary vessels. This is in part diagrammatic, for in reality the deeper row of venules cannot actually be seen in this plane.

A dorsal cutaneous vein accompanies each artery and each branch of the artery. The vein throughout its course on the surface lies dorsal to the artery but adherent to it. In the posterior region the artery may in some places be directly beneath (axial to) the vein but throughout its greater extent the artery lies approximately on the same surface plane though slightly deeper than the vein. The vein follows the artery as the latter runs mesially in the pectoral region. It passes between the intermusculature bones and ribs with the artery and since at no point does it cross the face of the artery it necessarily lies anterior to the artery in its transverse course to the heart. Approaching the heart the vein leaves the artery and turns anteriorly. Apparently it joins the Cuvierian duct, because latex injected into the cutaneous vein filled the Cuvierian duct. The details of this juncture were not investigated.

Both vein and artery are associated in the surface musculature with two distinct series of vessels. A segmental vein and artery is present in each segment running dorsally in the adjacent dorsal muscles. Comparable vessels occur ventrally in each segment and run in the superficial ventral musculature. From the parent vessels the dorsal segmentals curve posteriorly while the ventral segmentals follow a characteristic path. From their origin or confluence with the cutaneous trunks they run perpendicularly and then trend anteriorly to turn shortly posteriorly. Figure 51 illustrates this system. The dorsal segmental vessels are the larger and more conspicuous. The segmental artery crosses the internal face of the vein. Unlike *Euthynnus* the segmentals are equally developed in each segment. The ventral segmentals appear smaller and their injection was always incomplete. The ventral segmental arteries originate as discrete vessels in the cutaneous artery whereas the ventral segmental veins appear to consist of capillary strands or the fusion of several capillary strands.

Both vein and artery likewise receive or give rise to capillary sheets throughout their course on the surface. The dorsal cutaneous artery gives rise from its axial face to a continuous irregular row of arterioles each of which breaks up into a capillary bundle which collectively form a vascular sheet running axially. There may be, in addition, some irregular arterioles arising from other faces of the artery. However, these do not compare in frequency and regularity with the described row. The vein similarly receives two rows of venules, one superficial, the other deep. The latter row is the more numerous. These venules are closely spaced (one or two millimeters apart) and they discharge into the axial or proximal-axial face of the vein. The superficial row of venules are spaced roughly one-eighth inch apart. Each venule crosses the lateral face of the adherent artery and originates in a capillary sheet. Venous and arterial capillaries run axially in a narrow V-shaped plane. Both venules and arterioles appear to become less regular and numerous posteriorly.

The ventral branch of the cutaneous artery has a separate origin in the aorta. It generally arises beneath the junction of the fifth and sixth vertebrae just anterior to the dorsal branch. At its origin it forms an angle of roughly 50° with the aorta posteriorly. It runs thus for a fraction of an inch and then curves laterally. Approximately a half inch from its origin it branches into two. The smaller portion runs

anteriorly and dorsally and was not further investigated. The major portion continues laterally and ventrally towards the ventral extremity of the pectoral insertion. In this course it passed, in the one specimen thus investigated, anterior to the first rib on the right side and between the first and second ribs on the left side. Reaching the spinous portion of the postclavicle it turns abruptly posteriorly and passing between the third and fourth intermuscular bones (probably variable) it reaches the surface musculature in the vicinity of the ventral base of the pectoral insertion. In the surface musculature the ventral cutaneous artery consists of a short dendritic system in the immediate vicinity of the pectoral fin. The remainder of the ventral superficial musculature in this and the posterior regions is supplied principally through the ventral segmentals of the dorsal cutaneous artery. Although it was not investigated a vein accompanies each branch and the trunk of the ventral cutaneous artery. This was demonstrated by a partial and incidental injection.

The cutaneous system of *Auxis* is therefore differentiated from that of all other genera of this family by the fact that the ventral cutaneous artery arises directly in the aorta. It differs from *Euthynnus* in having the dorsal branch of the artery ventral to the corresponding vein. The cutaneous system of *Auxis* is therefore a positive diagnostic character.

Visceral Arterial

This system was completely injected in two specimens and partially in two others. There was a general agreement in all observations.

The coeliac mesenteric artery arises from the right side of the aorta, generally beneath the posterior half of the fourth vertebra. It curves laterally and posteriorly around the pharyngeal muscle and about three-fourths of an inch from its origin it gives off mesially a small Number I branch. One half inch or less beyond this it divides into two approximately equal major vessels, the Number II and Number III branches. There are thus three branches to this system in this species.

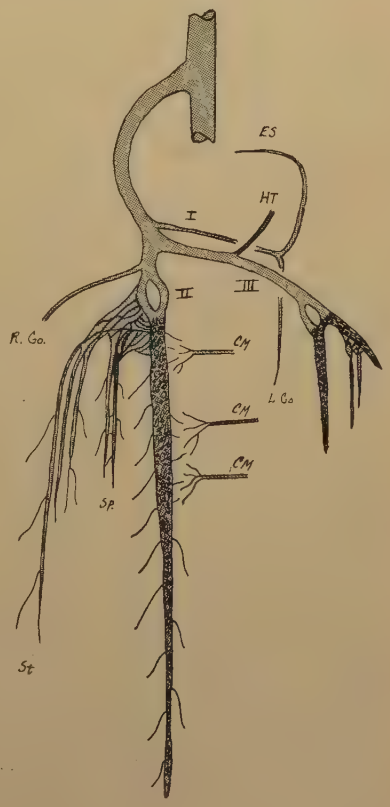

FIGURE 52. Frigate mackerel: Diagrammatic sketch of the coeliac mesenteric artery. CM = caecal mass. Es = esophagus. Ht = heart. L. Go = left gonad. R. Go = right gonad. Sp = spleen. St = stomach.

The Number I Branch. This small vessel runs transversely in the dorsal wall of the anterior stomach to the left side where it divides. One branch runs posteriorly in the mesentery to the head of the left gonad and continues towards the posterior end of this organ. The second branch continues in the wall of the stomach and runs ventrally and anteriorly to terminate in the ventral wall of the esophagus. There is no branch of the No. I on the left dorsolateral wall of the stomach.

The Number II Branch. Just beyond its origin the No. II branch gives rise to a small vessel which runs in the mesentery to the right gonad. Beyond this the No. II branch continues towards the liver. Meeting the right hepatic portal vein, this branch divides into several vessels which run in the walls of the right hepatic vein the length of this lobe. These parallel strands are profusely connected so that the vein is completely enmeshed by an arterial network. This is essentially comparable with *Euthynnus*. As in *Euthynnus* the separate vessels to other visceral organs arise as multiple strands from this network. These strands fuse into one or more larger parallel vessels running to the several organs.

From the head of the right lobe numerous strands emerge and fuse into at least three moderate parallel and adherent vessels which run posteriorly in the right dorsolateral wall of the stomach. All of these vessels terminate in branching systems towards the posterior extremity of the stomach and there is no evidence of an arterial loop such as was found in *Euthynnus*. Beyond the origin of these vessels another series arises to form two distinct anastomosing parallel vessels which run to the spleen. They branch throughout the substance of this organ. Emerging from the dorsal face of the right lobe are numerous moderate trunks which cross to the substance of the caecal mass. The origin of these vessels is confusing. They are formed within the liver by the fusion of innumerable arterial strands arising from the network surrounding the right hepatic vein. At the other end they break up into numerous terminal branches within the caecal mass and it is difficult to determine in which organ they originate. No major vessel was observed running to the intestine. There are numerous small vessels on the intestinal walls but the origin of these is obscure. The No. II branch thus supplies primarily the right lobe of the liver, the right dorsolateral wall of the stomach, the spleen and possibly the caecal mass.

The Number III Branch. From its origin this vessel continues ventrally and transversely to the left side running embedded in the head of the liver. In this course it gives rise to one small branch which runs roughly parallel with the trunk and appears to go to the heart or pericardial septum. The trunk of the No. III branch continues to the left hepatic portal vein. Here it divides into two branches which encircle this vein. The two branches meet at the confluence of the hepatic veins from the center and left lobes. Here they disintegrate into two separate networks surrounding respectively the hepatic veins in these two lobes. These networks are comparable with that in the right lobe. There are no separate and distinct visceral vessels beyond this point. Numerous strands emerge from the center lobe and run into the substance of the caecal mass. Anteriorly two such vessels cross from the caecal mass to

the anterior ventral wall of the stomach. Posteriorly several similar vessels pass from the dorsal face of the caecal mass to the ventral wall of the stomach. The entire arterial supply to the ventral wall of the stomach appears to come through these strands.

Emerging from the dorsal surface of the left lobe of the liver is an arterial strand which runs to the left anterior wall of the stomach. This terminates here in a short branching system and does not continue posteriorly as it does in *Euthynnus*. There is in *Auxis* no evidence of an arterial supply in the left dorsolateral wall of the stomach.

While this is a general description of the visceral arterial circulation, considerable minor departures from it should be anticipated in individual specimens. Thus in one case the supply to the right dorsolateral wall of the stomach came in part directly from the trunk of the No. II branch before that disintegrated in the liver. Other such variations should be anticipated.

The visceral arterial circulation of *Auxis* is distinctive. While it resembles in general that of *Euthynnus* it is in many ways less complex. It lacks the arterial loop described for *Euthynnus* and the branch supplying the left dorsolateral wall of the stomach. One receives the impression that the No. II branch is the most important and is perhaps a trifle larger at its origin than the No. III.

Postcardinal Vein

There is a large, conspicuous and characteristic postcardinal vein in this species. It emerges from the haemal canal through the first complete haemal arch which is generally on the 21st vertebra. As this and subsequent arches are deflected posteriorly almost to a horizontal position, the postcardinal remains superficially visible as far as the vertical through the 22d vertebra. As the vent is on the vertical through the 24th vertebra, the postcardinal is thus exposed throughout the entire length of the body cavity with the exception of the last centimeter or so. Throughout this extent the dorsal aorta lies adherent to the dorsal wall of the postcardinal, and when the ventral wall of the latter is opened in an injected specimen the aorta and the rows of arterioles present a striking picture. Between each arteriole is the aperture of a corresponding venule.

The body cavity of *Auxis* differs in one important respect from all other members of the Katsuwonidae. It extends posterior to the vent a distance approximating one centimeter. This extends the posterior extremity of the body cavity to the vertical through the 25th vertebra. The section posterior to the vent is divided into two lateral pockets by interhaemal spines beneath the anal fin rays. The gonads may extend into these pockets. In this character *Auxis* resembles the Pacific mackerel. In *Auxis* the posterior pocket on the right side was, in these specimens, longer than that on the left. This is probably fortuitous and without significance.

The postcardinal of *Auxis*, with its associated characters thus affords a positive diagnostic character. It should prove of value in evaluating the relationship of *Auxis* with other genera within and without this order.

GENERIC CHARACTERS OF THE SKELETON

The following description of the skeleton of *Auxis* is based upon the five specimens dissected, supplemented by a collection of 15 vertebral columns and crania in the collection at this laboratory. In addition, two columns and crania of the long-corseletted type were available for comparison. Moreover the descriptions and illustrations of *Auxis hira* and *A. maru* published by Kishinouye were compared with these findings, and upon this basis the writer has discussed the generic as well as the specific characters of the skeleton. Such conclusions are obviously limited to the material included.

Cranium

Lateral View

The dorsal outline of the skull constitutes a single smooth curve, with the supraoccipital crest blending into the outline of the frontal and temporal crests. The supraoccipital crest is low anteriorly and relatively low distally, where it is produced posteriorly to or beyond the tip of the first neural spine as a tapered narrow wedge, ending in a terminal angle in the magnitude of 25°. The supraoccipital crest impinges in most cases against the excessively developed and high exoccipital ridge, of which the posterior margin blends into that of the supraoccipital crest to form a single relatively straight line. This character is an accentuated development of the condition peculiar to *Euthynnus*.

The ventral outline supplements the dorsal to form an infallible generic character. The posteroventral outline which resembles that of *Euthynnus*, is differentiated by two generic characters, one of which is relative while the other is positive. Relatively the posterior orifice of the myodome is far more vertical in this genus, with the result that it projects more conspicuously in outline than in *Euthynnus*, where the orifice approaches the horizontal. The positive character consists of a narrow tapered projection of the basioccipital on each side, which extends posteriorly at least one-half and generally the full length of the first vertebra. This is unique and striking, and differentiates *Auxis* from the bonito and all other species of the Plecostei.

Dorsal View

Auxis differs from all other species of Plecostei in the absence of paired foramen in the posterior margin of the frontals. It differs also in the shape of the ethmoid, which in *Auxis*, is unmistakably diamond-shaped with a point of the diamond anteriorly. In the bonito and in the Thunnidae this margin is transverse (or slightly concave) with a slight median protrusion, while in *Euthynnus* and *Katsuwonus* there is a pronounced median protrusion with the transverse margins curving into this. Although there are significant and numerous other differences between *Auxis* and other genera, the above differences will suffice to identify positively this view of the *Auxis* skull.

Ventral View

Auxis can be positively separated from *Sarda* and all species of the Plecostei by the excessive and unique development of the spine-like posterior projection of the basioccipitals. These processes extend posteriorly a distance equal to at least one-half the length of the first

FIGURE 53. Skull of *Auxis thazard*. Dorsal, ventral and lateral views. Blocking of the negative of the lateral view introduced an error in ventral outline. The dotted line indicates the actual outline of this portion of the parasphenoid.

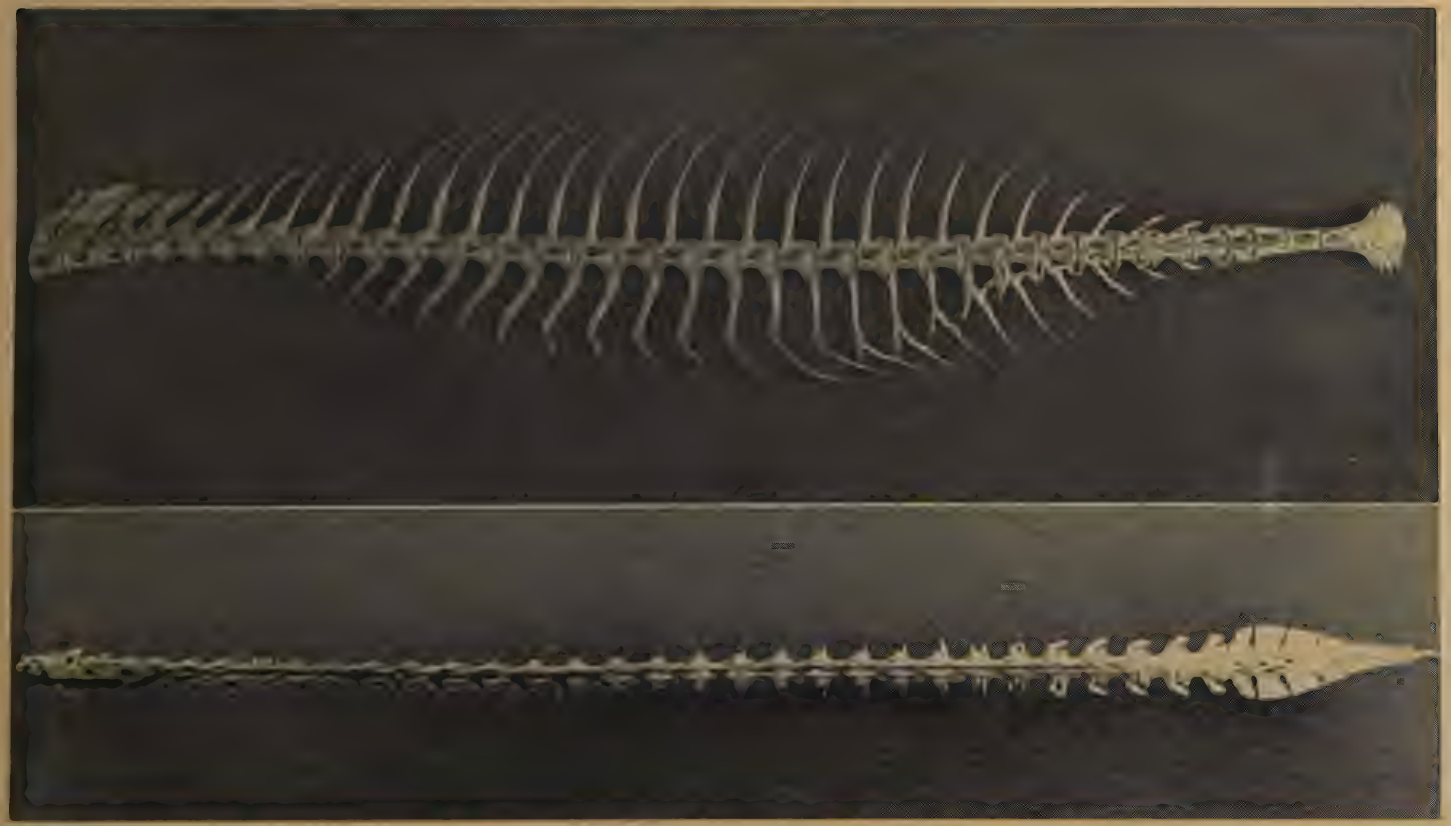

FIGURE 54. Frigate mackerel: Lateral and dorsal views of the vertebral column

vertebra, and generally the full length of the first vertebra. The two processes are separate and do not meet dorsally. They extend the apparent dorsal margin of the myodome far posteriorly, giving it—in this view—an almost horizontal aperture.

While there are numerous indicative differences separating and characterizing *Auxis*, one is worthy of comment. The excessively deep and large depression behind the prootic, characterizing the Plecostei, tends in *Euthynnus*, and more so in *Auxis*, to be roofed ventrally by a posterior extension of bone that is probably a part of the prootic. While this extension is quite variable in size and shape the average length of this bone gives the recess a kidney-shaped aperture in this view. In *Auxis* the ventral extension of the prootic takes the form of a blunt, roughly rectangular, projecting plate of bone which almost completely divides, in this view, the mouth of the depression into two portions. In extreme cases this character is specifically diagnostic, but there is considerable overlapping variation between *Auxis* and *Euthynnus*.

Vertebral Column

The major observed characteristics of the vertebral column are tabulated below.

Character	*Count*	*No. examined*	*Extent of variation*
Total number of vertebrae	39	22	None
Number of precaudal vertebrae	20	4	None
Caudal vertebrae	19	4	None
1st completed haemal arch on	21st vert.	3	None
1st haemal bridge on	27th vert.	19	25 to 27

The first ventrally projecting parapophyses are normally on the eighth vertebra. These, however, are small and inconspicuous; but are distinct and unmistakable on the ninth vertebra. The haemal process is branched on each side, as in *Euthynnus*, from the 21st vertebra posteriorly. The posterior branch constitutes the haemal arch. The anterior branch is initially a minute ventrally projecting spur, which becomes longer on succeeding vertebra until it approximates, and sometimes fuses with the haemal arch of the preceding vertebra.

The spinal column of *Auxis* is in many respects unique. Because it has been incompletely described (Starks, Kishinouye) the writer's observations are here recorded. One obscure but invariable character is the size of the 33d vertebra which is always smaller than adjacent ones. Those immediately anterior to the 33d are approximately uniform in length, and the 34th, 35th, and 36th are roughly equal in length. Sandwiched between, the 33d vertebra is noticeably and unmistakably shorter. This was true in every one of 18 specimens examined.

The pedicle (of Starks, or the epihaemal process of Kishinouye) in *Auxis* is far longer than in *Euthynnus* or *Katsuwonus*. It differs significantly from the latter two genera in that it consists, in all but a few posterior vertebrae, entirely of the haemal process. The inferior zygapophysis (of Starks) takes no part in the formation of the pedicle in *Auxis* anterior to the 25th, 26th or generally the 27th vertebra. In this respect it is unmistakably different from all other genera of the Katsuwonidae. The trellis-work of the haemal canal characterizing this family is rudimentary in *Auxis* and confined to a few posterior vertebrae.

The shape of the haemal canal is generically characteristic. The anterior arches are extremely elongated and narrow, which appears to result from the fact that the plane of the aperture approximates the horizontal. This alone distinguishes *Auxis* from all related genera and from the bonito.

In *Auxis* there is no ventral median plate of bone on the centrum of each vertebra, with the result that the ventral outline of each (central) vertebra is spool-shaped and not relatively straight as in *Euthynnus* and *Katsuwonus*. This again is a diagnostic character.

One of the most striking characters of *Auxis* is seen in dorsal or ventral view of the vertebral column. On each vertebra from the 18th to the 27th inclusive, there is an apophysis projecting laterally on each side in the median lateral line from the anterior end of the vertebra. These apophyses although rarely exceeding two mm. in length, are regular and conspicuous, and are inclined slightly forward. They are rudimentary on two or three vertebrae preceding the 18th, and become slightly and progressively longer up to about the 24th vertebra, beyond which they decrease slightly in length. From the 27th vertebra posteriorly, they are obscured by the development of an associated structure. On this and subsequent vertebrae there is a small apophysis developed laterally from the posterior end of each vertebra. This is flat (dorsoventrally) and is directed—or turns—posteriorly. It increases in expanse progressively through the 29th vertebra, and on the 29th, 30th and 31st vertebrae it is approximately equally developed, being roughly four mm. in length (longitudinally), and extending about the same distance from the centrum. On the 32d vertebra this process is greatly expanded and constitutes, with the comparable structures on the 33d and 34th vertebrae, the principal portion of the caudal keel. While this character is incipient in the Thunnidae, slightly more developed in *Euthynnus*, and even more so in *Katsuwonus*, it is only in *Auxis* that these processes become conspicuous. No other genus could thus be confused with *Auxis*.

The parapophyses on the first two vertebrae are also diagnostic of this genus. They are long and so oriented as to constitute a generic pattern. That on the first vertebra extends posteriorly, reaching approximately to the middle of the second vertebra. It abuts, throughout its greater extent, against the parapophyses on the second vertebra, which projects posterolaterally at an angle of approximately 30° with the vertebral column (Figure 54). No other species investigated has structures quite comparable, and this character alone will differentiate the spinal column of *Auxis* from *Sarda* and all species of the Plecostei.

Although the shape of the second neural spine is variable, it is nevertheless sufficiently characteristic to constitute a strongly indicative if not a positive character (Figure 54). It is invariably broadly expanded, with a straight dorsal and generally a straight upper posterior margin. In conjunction with the shape of the first and third neural spines, it will separate *Auxis* from *Sarda* and all species of the Plecostei excepting *Katsuwonus*. Extreme variants of *Katsuwonus* may be confused with it.

The vertebral column of *Auxis* cannot be confused with that of any other species discussed. Innumerable characteristics can be used to

identify it. Of these, the most serviceable ones are the number of vertebrae and the structure of the pedicle. In fact the latter alone furnishes positive identification. With 39 vertebrae *Auxis* is readily distinguished from *Katsuwonus* and *Sarda*. The presence of the pedicle in *Auxis* immediately separates it from all the Thunnidae. The absence in *Auxis* of a major contributing component of the pedicle arising in the inferior zygapophysis, eliminates *Euthynnus*.

SPECIFIC DIFFERENCES IN THE SKELETON

Insofar as a comparison can be made of a specimen with an illustrated description, no differences could be detected between the skeletons of *A. hira* and *A. thazard*. Similarly the columns and crania of the long-corseletted type accorded with Kishinouye's description of *A. maru*. Hence the present discussion is actually a comparison of the short-corseletted (*thazard*) type with the long-corseletted variety.

The skull is narrower in the long-corseletted type than in *thazard*. Measuring the width between the widest points of the pterotic processes, and the length of the skull from the tip of the vomer to the concave ventral tip of the posterior aperture of the myodome (both of which are unsatisfactory reference points) the ratio of width to length was 1.37 and 1.38 in the two specimens of the long-corseletted type, and it ranged from 1.29 to 1.38 in 15 specimens of *thazard*. Despite this overlap, there was generally a visual difference in proportions.

The posterior projections of the basioccipitals, characterizing this genus, are more pronounced and of greater length in *A. thazard* than in the long-corseletted form. However, there is overlapping variation and although this character will separate most specimens of the genus, it will not identify all.

The shape of the ethmoid, in dorsal view, will identify the majority of specimens. In *A. thazard* this bone is invariably diamond shaped with relatively straight margins on all four sides. In the long-corseletted type the ethmoid, while basically the same in shape, has concave anterior margins with a centrally produced squared process anteriorly. Moreover the two posterior sides of the diamond are not straight but erratic in outline. In the collection at hand, there was only one specimen that could not be positively typed by this character.

The orbit is deeper in the long-corseletted type, and its posterodorsal outline slopes upward anteriorly in a long curve, giving it a broadly ovoid outline. In *thazard* the orbit is more rectangular, proportionately longer and of less height. Although this is a visual, qualitative character, it was possible to type every specimen without exception.

The difference in the shape of the orbit is due in part to a difference in the shape of the ventral margin of the parasphenoid. In *thazard* the columnar portion of the parasphenoid is straight and flat, whereas in the long-corseletted type it is distinctly bowed downward, with the upper margin concave. It was sufficiently different to be diagnostic in every specimen.

In the material on hand a positive difference exists in the posteroventral aspect of the skull seen in lateral view. In both specimens of the long-corseletted type there is a posteriorly projecting beak, or short process, in that portion of the parasphenoid that forms the floor of the

myodome. In all (15) specimens of *thazard* this is lacking, and the contour of this portion of the skull enabled a positive identification in every case. The difference is also apparent in ventral view. As a result of this beak-like process, the posterior aperture of the myodome in the long-corseletted type has a tongue of bone projecting into the aperture, which in *thazard* is a fairly regular oval. Likewise the posterior orifice of the myodome is relatively high in *thazard,* whereas it is dorsoventrally compressed in the long-corseletted type.

In the dorsal view of the skull of the long-corseletted type the temporal crests are (visually) exactly parallel with each other and with the supraoccipital crest. In *thazard* the temporal crests diverge anteriorly, so that the three crests are distinctly not parallel. Of the 17 specimens examined and thus identified only one was questionable.

The differences in the vetebral columns of these two types are less positive, and appear to be of the type necessitating statistical differentiation. This is also true of those specific characters enumerated by Kishinouye as separating *A. maru* from *A. hira.* Thus, the difference (illustrated by Kishinouye) in the structure of the parapophyses on the first two vertebrae is variable, and in the present collection instances were found in which *thazard* was identical with the long-corseletted form. The absence of inferior foramen in the vertebrae of *A. maru* (the long-corseletted type) is not a positive character. In the two specimens on hand (of the comparable type) inferior foramen are present, but they are fewer in number and more posteriorly located. In *thazard* there are generally conspicuous foramen on four caudal vertebrae whereas in the long-corseletted type there are two or three relatively inconspicuous ones. Moreover, in *thazard* the first such foramen (formed by a bridge of bone connecting the inferior zygopophysis of one vertebra with the haemapophysis of the preceding vertebra) occurred on the 27th vertebra, whereas in the long-corselleted type it occurred on the 28th and 29th vertebrae respectively of the two available specimens.

The individual bones of *thazard* were examined but as no comparable bones of the long-corseletted form were available for comparison, a description of such bones is not attempted.

It is well established that there are two distinct forms or types of *Auxis* on both sides of the Pacific, namely, the long and the short corseletted varieties. However, there is apparent confusion in the classification of the species, and without a detailed search of the literature and a simultaneous examination of comparable specimens, it is impossible to determine whether the several described species are valid or the names synonymous. Until such time as the comparison is made, the common short-corseletted variety of the eastern temperate Pacific, which is herein described, is provisionally designated *Auxis thazard.*

The present description has been closely compared with that, by Kishinouye, of *A. hira,* and the two descriptions are almost interchangeable. Only in the gill raker count is there an apparent difference. *A. hira* is credited with $9 + 30 = 39$ rakers, whereas *thazard* is herein described with $10(10\text{-}11) + 1 + 33(31\text{-}34) = 45(42\text{-}45)$. Whether such a difference, alone, would justify a species separation is a matter of opinion. It seems probable that such a biometrical difference would disappear with extensive collections, and at most suggest overlapping populations over the extensive area of the Pacific.

BLACK SKIPJACK (*Euthynnus lineatus*)

The following description was written originally in December, 1942, based upon the dissection of two specimens taken October 10, 1941, at a point 4.4 miles, 143° true, from Redondo Point Light, at the entrance to Magdalena Bay, Baja California.

In the course of the present assignment additional material was collected in 1952, and the original work duplicated, checked and extended. Hence this description is now based upon 34 specimens, most of which were subjected to a thorough examination. The remainder of the material was used to check specific characters. The precise origin of some specimens handled is not known. Some were picked from loads of yellowfin tuna and skipjack in the course of routine sampling and in some instances no information could be obtained as to the precise origin of the fish. All such specimens, however, were caught along the Mexican and Central American coastline, or at the Galapagos Islands. The origin of the specimens handled is listed below.

Specimen No.	*Body length*	*Date taken*	*Origin*
1	588	Oct. 10, 1941	Entrance of Magdalena Bay, Baja California
2	605	Oct. 10, 1941	Entrance of Magdalena Bay, Baja California
3	605	Dec. 9, 1949(?)	Unknown: Baja California or Central America
4	596	May 5, 1952	Unknown: Baja California or Central America
5	440	1952	Unknown: Baja California or Central America
6	442	1952	Unknown: Baja California or Central America
11	311	Oct. 17, 1952	Baja California, 23° 36.5′ N., 109° 26.5′ W.
12	322	Oct. 17, 1952	Unknown: Baja California or Central America
13	316	Oct. 17, 1952	Unknown: Baja California or Central America
14	318	Oct. 17, 1952	Unknown: Baja California or Central America
15	318	Oct. 17, 1952	Unknown: Baja California or Central America
16	317	Oct. 17, 1952	Unknown: Baja California or Central America
17	603	1952	Unknown: Baja California or Central America
18	616	1952	Unknown: Baja California or Central America
19	520	Oct. 1952	Galapagos Islands
20	574	1952	Unknown: Baja California or Central America
21		1952	Unknown: Baja California or Central America
22		Nov. 23, 1952	Santo Domingo Point, Lower California, 26° 19′ N., 112° 39′ W.
23		Nov. 23, 1952	Santo Domingo Point, Lower California, 26° 19′ N., 112° 39′ W.
24	583	Nov. 23, 1952	Santo Domingo Point, Lower California, 26° 19′ N., 112° 39′ W.
25		Nov. 23, 1952	Santo Domingo Point, Lower California, 26° 19′ N., 112° 39′ W.
26	492	Nov. 23, 1952	Santo Domingo Point, Lower California, 26° 19′ N., 112° 39′ W.
27		Nov. 23, 1952	Santo Domingo Point, Lower California, 26° 19′ N., 112° 39′ W.
28	472	Jan. 1953	Peru Bank, 3° 35′ S., 80° 55′ W.
29	446	Nov. 3(?), 1952	Galapagos Islands
30	427	Dec. 8, 1952	Culpepper Island, Galapagos
31	613	Jan. 2, 1953	Tortuga Island, Galapagos
32	514	Dec. 7, 1952	Upper Tomaco (Colombia) Bank, 2° 08′ N., 79° 10′ W.
33	432	Dec. 20, 1952	Upper Tomaco (Colombia) Bank, 2° 08′ N., 79° 10′ W.
34	476	Jan. 21, 1953	Lower Tomaco (Colombia) Bank, 1° 40′ N., 79° 40′ W.
35	455	Jan. 21, 1953	Lower Tomaco (Colombia) Bank, 1° 40′ N., 79° 40′ W.
36	484	Dec. 27, 1952	Upper Tomaco (Colombia) Bank, 2° 08′ N., 79° 10′ W.
37	443	1952 (?)	Unknown: Probably Colombia or Peru Bank
38	462	1952 (?)	Unknown: Probably Colombia or Peru Bank or Galapagos Islands

EXTERNAL CHARACTERS

This species can in most instances be readily identified by the dorsal markings. The general pattern consists of a series of three, four or five broad continuous black stripes running horizontally on the back from the corselet to the caudal fin. The most ventral of these stripes in-

FIGURE 55. Black skipjack, *Euthynnus lineatus*. Taken October, 1949, Morgan Bank, Baja California.

variably starts anteriorly below the lateral line and generally crosses this in its path to the caudal region. Variations consist mainly of interruptions in the continuity of the stripes, or branching of individual stripes with supplementary short irregular markings between. However, variations can be sufficiently extreme to preclude a positive identification and such variations widely overlap the markings of other described species (Figure 56). The markings, however, are not the sole justification for the separation of this species. They are associated with diagnostic skeletal differences which are specific and positive.

In the course of this work the author attempted to evaluate the pattern of markings as a diagnostic character. All the aberrantly marked forms collected were segregated and the dissections reserved until the close of the study. When all normally marked specimens had been examined and the characters of this species firmly established, the aberrant forms (of which there were 10) were withdrawn from storage and arranged in order of the degree of departure from the normal color pattern. This procedure revealed progressive and continuous variation in markings from the normal to a pattern that approached the distinctive crescentic markings characterizing *E. alletteratus* from the Gold Coast (Irvine, 1947). Between these extremes were specimens that could be as readily assigned to one as another of the species described in the literature. Furthermore, two of the ten specimens differed on the two sides of the same fish. In one in particular, the markings on one side were distinctly of the *lineatus* type, whereas on the other they were broken and oblique, and of themselves could have been interpreted as a variation of any of the three species discussed in this work.

The most divergent specimen was then subjected to a careful and complete dissection. Apart from the external markings, not a single character differed from the condition of the typical *lineatus*. Each of

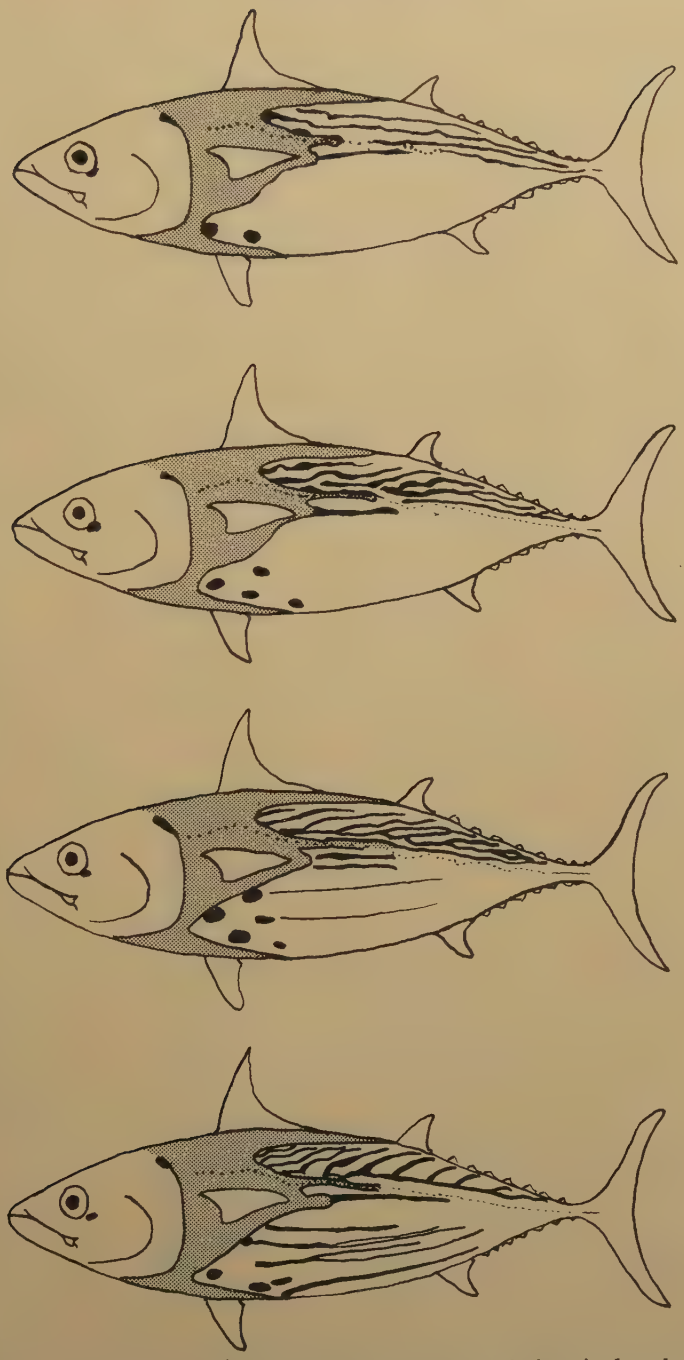

FIGURE 56. Black skipjack: This figure illustrates the variations in dorsal markings. The upper figure represents the typical pattern of continuous horizontal lines, while the lowest figure depicts an extreme variant. Occasionally the markings differ on the two sides of a fish. The figures illustrate also the course of the lateral line in these specimens, and variations in the shape of the ventral bulge of the corselet. The outlines of these fish were purposely traced from Fraser-Brunner's (1949) figures in order to facilitate direct comparison with those figures.

these 10 aberrant specimens possessed the positive diagnostic skeletal characters identifying *lineatus* beyond any doubt.

In view of this one must conclude that the markings are extremely variable and entirely unreliable for positive species differentiation. While they serve to advantage as a corroboratory character their use in any scheme of classification will only lead to confusion and conceal the true identities. Thus, Fraser-Brunner (1949) in his revision of the genus *Euthynnus* has, influenced largely by color pattern, assigned as subspecies of a single species two forms (*E. lineatus* and *E. yaito*) possessing consistently different vertebral counts and skeletal structures.

Mr. H. B. Clemens, who collected many of these aberrantly marked forms, states that such forms were common in all schools fished. He estimated that about 10 percent of the catch differed sufficiently from the typical *lineatus* markings to warrant a closer inspection.

Again illustrating the unreliability of markings, the writer received a locally caught specimen of *Euthynnus* that differed conspicuously in markings from the *lineatus* pattern but could not be distinguished positively from the aberrant forms of the latter. A positive identification of this specimen as *E. yaito* was, however, readily made upon checking the vertebral count and skeletal structures.

These black dorsal stripes are superimposed upon a background of blue, deepening into black dorsally and shading into grey and silver below. In a freshly caught specimen the appearance is quite striking, because of the sharp demarcation of the blue area by the scaled corselet.

The belly of the fish is dusky or silvery with an irregular number (usually from 2 to 6) of black spots between the pectoral and pelvic fins. Such spots are not diagnostic or invariable, for specimens are occasionally seen with no apparent spots. At the other extreme many specimens have distinct and unmistakable oblique black or dark stripes running on the belly from below the pectoral toward the caudal region. The appearance suggests that the belly spots may be the remnants of previously existing black belly stripes, but as a matter of record the stripes are frequently present on large fish, whereas they have not been observed on the small immature fish which I have examined. In the latter the spots are sharp and discrete.

In most of the specimens there is an irregular small black spot adjoining the posteroventral margin of the eye. The dorsal (or inner) surface of the ventral fins is black or nearly so, margined or tipped distally with white. Irregular streaks or flecks of white are commonly found between the rays.

The dorsal fins are contiguous, with the first dorsal about twice the height of the second. The distal margin of the first dorsal is strongly concave, with the first spine the longest. There are 14 or 15 rays in the first dorsal fin and 11 or 12 rays in the second dorsal. There are usually eight dorsal and seven anal finlets; however, in one specimen the count was nine and eight respectively. The lateral caudal keels are inconspicuous and are indicated superficially only by a dorsoventral flattening or ellipticity of the caudal peduncle.

The lateral line is not specifically distinct. There is a gentle rise, or a slight peak above the pectoral fin. In about half the specimens this rise simulated a long, low wave. In the remaining specimens the slopes were straight, with the result that the crest became a peak, accentuating the rise. Posterior to this the line subsides and runs as a relatively straight line to the caudal peduncle without regular conspicuous undulations. In roughly half the specimens examined there was a slight ventral dip in the line beneath the second dorsal fin. In shape and location this, when present, was relatively constant, and was the most marked of the negligible undulations present.

The corselet is in general similar to that of all species of *Euthynnus*. The scales extend posteriorly as a narrow ribbon over the lateral line, diminishing in width posteriorly. Beneath or ventral to this posterior projecting ribbon is a second bulge or projection. The extent of this is quite variable, but it is always relatively short. In the 17 specimens in which this character was measured, the distance from the tip of the pectoral to the tip of this corselet projection varied from 0.15 to 0.47 of the length of the pectoral fin.

In 7 out of 11 specimens the origin of the anal fin was on the vertical through the insertion of the first dorsal finlet. In 3 of the 11 it was on the vertical dividing the distance between the end of the second dorsal base and the insertion of the first finlet, and in one it was below the insertion of the second dorsal finlet. The insertion of the anal fin is thus relatively far posterior.

Palatine teeth are present in all specimens and conspicuous in most. Vomerine teeth are likewise present in all specimens, though in some they were difficult to discern, and in one specimen no teeth could be felt, but the longitudinal ridge of bone supporting the teeth was apparent to the touch.

There are anterior gill rakers on the first arch only. These are long and numerous. There is present in all specimens a raker at the angle of this arch with a basal process projecting both dorsally and ventrally. This appears to be a generic character. The gill raker count is 9(7-11)+1+27(23-29)=37(32-41). At the angle of the second and third arches there are generally two or three rudimentary rakers. The upper arm of the fourth arch has rudimentary rakers along its entire length, and that of the third arch frequently has such rakers over part of its length. While such rakers are rudimentary, they may in occasional specimens be appreciably developed, and in at least two specimens the longest measured three or four millimeters in length. Hence, the statement that gill rakers are present on the first arch only must be taken with reservations. Posterior rakers or gill teeth are present on all arches, but are longest and most developed on the first where there are approximately 30 such gill teeth. They become progressively less developed on succeeding arches.

There is a dorsally projecting lateral cartilaginous ridge on each margin of the tongue. This is invariably present though not equally developed in all specimens. In some they were high and conspicuous, and in others they were low.

The interpelvics are divided as in all species of this genus, but considerable variation characterizes this structure. The two portions are frequently unequal in length, and the depth of the dividing cleft is variable.

There are from 25 to 30 teeth on each side of the lower jaw. This is an approximate count made consistently on approximately 10 specimens. No precise count was attempted.

The posterior margin of the operculum is straight, with an angular posteroventral edge, as in all species of this genus. Similarly, the free margin of the preoperculum is smoothly rounded. The maxillary extends to the vertical through the center of the eye, but not beyond. In this respect it differs from *E. yaito*, in which the maxillary reaches beyond this vertical.

The available measurements are listed in Table 10 and the meristic counts in Table 11. Discussion of these appears in a later section.

INTERNAL ANATOMY

The caecal mass and the liver are the dominant organs in the ventral view of the viscera (Figure 57). The center and left lobes of the liver are conspicuous at the anterior end of the body cavity, and the right lobe is by far the longest and extends almost the full length of the body cavity. It lies on the right side of the fish and is conspicuous in all but small specimens. In the latter it is largely concealed and only the median margin is exposed at the cut surface of the body wall. In the majority of specimens a small section of the intestine shows posteriorly in the median line. In some the maturing gonads show posteriorly especially on the left side. In others the posterior tip or extremity of the stomach is visible on the left side of the fish. As in other species of this genus the gall bladder and the spleen are concealed in ventral view, but in occasional specimens a small portion of the gall bladder can be seen. The generic pattern is emphasized by the conspicuous hepatic veins which show on the ventral surfaces of all lobes.

The ventral view of the viscera, although not diagnostic, is useful in the separation of *lineatus* from *alletteratus*. In the latter species the attenuated portion of the right lobe of the liver is roughly median in position, and lies ventral to the remaining viscera, so that its entire width is seen. In *lineatus* this lobe is more lateral and oblique in expanse, and one sees more or less of the mesial portion only of this lobe.

In occasional specimens of *lineatus*, one sees a suggestion of the mosaic pattern described for *E. yaito*. This is caused by the presence of an incipient fat organ on the posterior ventral wall of the stomach, by a ribbon of fat in the posterior intestinal membrane and lastly by lobulation within the substance of the caecal mass. Although in no instance did the development of this mosaic approach the condition commonly found in *yaito*, nonetheless it is sufficiently similar in these occasional specimens to eliminate the character as peculiar to *yaito*.

TABLE 10

Black Skipjack: The Measurements Made Upon 29 Specimens, and the Range in the Resulting Ratios, of Which Body Length Is the Numerator in Each Case Except Those Indicated by an Asterisk. In the Latter the Head Length Becomes the Numerator.

	Fish number													
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 11	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18
Body length	588	605	605	596	440	442	311	322	316	318	318	317	603	616
Head length	173	171	180	172	123	122	87	92	90	90.5	91	90	173	180
1st dorsal insertion	182	185	194	190	139	143	95.5	102	95	103	99	101	185	193
2d dorsal insertion	345	348	360	354	263	266	177	188	184.5	189.5	189.5	191	336	367
Anal insertion	386	392	398	397	292	292	211	214	205.5	206	213	212	389	411
Ventral insertion	193	191	198	189	136	136	101	105	100	99.5	102	102	188	201
Greatest body depth	144	132	155	160	112	118	ca 71	ca 75	ca 73	75.5	75.5	77	149	170
Greatest body width	98	98	102											
Dorsal-ventral distance	136	133	149	153	107	110	68.5	73.5	72	74	73.5	75	145	159
Dorsal-anal distance	239	242	250	247	183	188	130	131	131.5	129	133	133	241	258
Ventral insertion to vent			207	216	161	159	111	110	107.5	107	113	109	203	218
Length 1st dorsal base	173	172	173	170	128	130	84.5	87.5	92	89	94	94	156	179
Length 2d dorsal base	33	35	35	39	26	26	19	22	21	20	18	18	32	34
Length of anal base	32	31	35	37	24	27	18	19	20.5	17	18.5	19	30	34
Pectoral length	97	97	93	94	69	67	44.5	49	48	47.5	49	48.5	92	98
Height of 1st dorsal	78	83	82	81	65	62	40	42	ca 41	41	41	40.5	84	ca 91
Height of 2d dorsal	37	43	41	41	28	27	20	ca 22	19	19.5	20	21	45	44
Height of anal	35	41					17	20	19	19	20	21	45	42
Diameter of iris	26	25	27	24	17		14.5	14	14	14	14	14	ca 22	ca 24
Maxillary length	65	65	70	66	48	47	35	37	36	36	35	36	66	70
Snout to posterior margin of eye				72	54	62								

TABLE 10—Continued

Black Skipjack: The Measurements Made Upon 29 Specimens, and the Range in the Resulting Ratios, of Which Body Length Is the Numerator in Each Case Except Those Indicated by an Asterisk. In the Latter the Head Length Becomes the Numerator.

	Fish number															
	No. 19	No. 20	No. 24	No. 26	No. 28	No. 29	No. 30	No. 31	No. 32	No. 33	No. 34	No. 35	No. 36	No. 37	No. 38	Ratios
Body length	520	574	583	492	472	446	427	613	514	432	476	455	484	ca 443	462	
Head length	150	167	170	157	137	138	123	176	148	116	136	132	137	132	134	3.13– 3.72
1st dorsal insertion	165	186	183	broken	150	158	133	197	160	129	146	142	145	145	143	2.82– 3.35
2d dorsal insertion	306	345	340	326	283	293	252	367	299	249	278	267	280	ca 269	272	1.51– 1.79
Anal insertion	336	384	386	359	308	315	281	408	339	280	305	295	316	292	302	1.37– 1.56
Ventral insertion	164	182	------	178	154	153	137	198	167	132	153	146	168	147	154	2.76– 3.27
Greatest body depth	132	157	------	148	ca 123	131	------	------	128	------	------	------	------	------	------	3.32– 4.58
Greatest body width	ca 85	------	------	------	ca 79	------	------	------	ca 85	------	------	------	------	------	------	5.93– 6.17
Dorsal-ventral distance	128	147	------	------	116	127	------	------	120	------	------	------	------	------	------	3.51– 4.55
Dorsal-anal distance	210	241	------	------	192	204	------	------	210	------	------	------	------	------	------	2.19– 2.50
Ventral insertion to vent	180	206	------	187	157	170	144	205	175	147	149	153	153	143	150	2.62– 3.19
Length 1st dorsal base	146	168	------	broken	137	143	------	------	145	------	------	------	------	------	------	3.12– 3.86
Length 2d dorsal base	32	33	------	------	30	34	------	------	31	------	------	------	------	------	------	13.12–18.84
Length of anal base	31	31	------	------	24	30	------	------	31	------	------	------	------	------	------	14.87–20.10
Pectoral length	84	88	------	89	78	84	------	------	87	------	------	------	------	------	------	5.31– 6.99
Height of 1st dorsal	66	72	------	broken	64	71	------	------	76	------	------	------	------	------	------	6.28– 7.97
Height of 2d dorsal	33	broken	------	------	33	35	------	------	36	------	------	------	------	------	------	12.74–16.63
Height of anal	34	ca 45	------	------	36	35	------	------	35	------	------	------	------	------	------	12.74–18.29
Diameter of iris	23	ca 20	------	20	------	20	------	------	19.5	------	------	------	------	------	------	*6.00– 7.85
Maxillary length	59	65	------	57	53	52	------	------	57	------	------	------	------	------	------	*2.48– 2.75
Snout to posterior margin of eye	------	------	------	------	ca 58	------	------	------	62	------	------	------	------	------	------	*1.97– 2.39

TABLE 11

Black Skipjack: Meristic Counts Made Upon 34 Specimens

	Fish number																
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 11	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18	No. 19	No. 20	No. 21
1st dorsal rays	15	15	13	14	15	15	14	15	14	14	15	14	14	15	14	14	15
2d dorsal rays	11?	11?	12	------	------	11	------	------	------	------	------	------	------	------	11	11	11
Dorsal finlets	8	8	8	8	8	8	8	8	8	8	8	8	9	8	8	8	8
Anal rays	11	11	12	------	------	11	------	------	------	------	------	------	------	------	------	12	12
Anal finlets	7	7	7	7	7	7	7	7	7	7	7	7	8	7	7	7	7
Gill rakers:																	
Upper limb	10	10	------	9	9	------	9	10	9	10	10	9	------	9	------	10	9
Angle	------	------	------	1	1	------	1	1	1	1	1	1	------	1	------	1	1
Lower limb	27	26	------	25	27	------	25	27	27	28	26	26	------	24	------	27	26
Total count	37	36	------	35	37	------	35	38	37	39	37	36	------	34	------	38	36

Black Skipjack: Meristic Counts Made Upon 34 Specimens

	Fish number																
	No. 22	No. 23	No. 24	No. 25	No. 26	No. 27	No. 28	No. 29	No. 30	No. 31	No. 32	No. 33	No. 34	No. 35	No. 36	No. 37	No. 38
1st dorsal spines	------	------	------	------	------	------	14	15	------	------	14	------	------	------	------	------	------
2d dorsal rays	------	------	------	------	------	------	11	12	------	------	11	------	------	------	------	------	------
Dorsal finlets	------	------	------	------	------	------	8	8	------	------	8	------	------	------	------	------	------
Anal rays	------	------	12	------	------	------	11	12	12	13	13	11	12	12	12	12	12
Anal finlets	------	------	------	------	------	------	7	7	------	------	7	------	------	------	------	------	------
Gill rakers:																	
Upper limb	9	8	9	9	10	10	10	7	9	8	9	11	9	9	11	10	8
Angle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lower limb	28	26	26	26	27	25	26	25?	27	23	27	26	28	26	29	26	26
Total count	38	35	36	36	38	36	37	33	37	32	37	38	38	36	41	37	35

Caecal Mass

In the ventral view of the viscera the caecal mass is a triangular or wedge-shaped organ, with the apex lying posteriorly, generally but not

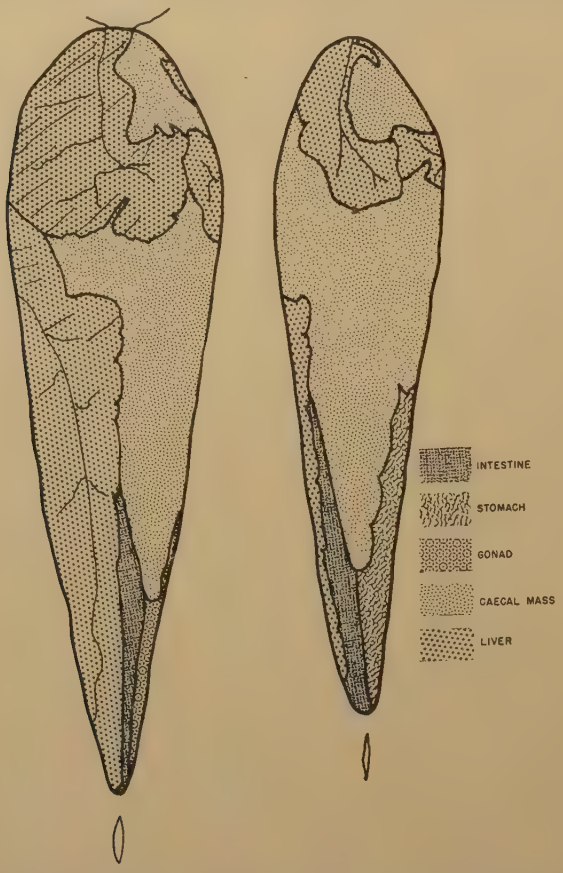

FIGURE 57. Black skipjack: Ventral view of the viscera, *in situ*. Sketch on right is from a small specimen. The right lobe of the liver generally occupies a position intermediate between these two views.

invariably on the left side of the body cavity. Upon the broad end of the wedge, anteriorly, the center and left lobes of the liver are, in appearance, superimposed and so intimately associated that it is difficult to separate the two organs. Actually, an arm of the caecal mass projects dorsally on either side and completely envelopes the duodenal region of the intestine. Into the latter empty six or seven caecal ducts. The largest of these branches into a complex vascular system throughout the triangular apex of the caecal mass.

The surface of this organ is smooth, with no indication of individual caeca. Such, however, are present and may be distinctly seen under magnification. In stale specimens the texture appears granular.

In small specimens the caecal mass is proportionately larger, and almost covers the entire ventral surface of the remaining viscera.

In occasional specimens the left margin and the apex of the caecal mass are more or less lobulated, with deep indentations, and with the resulting lobes being further divided into lobules or cells. In such specimens the major lobes are often nonadherent, or perhaps loosely adherent, so that they can be readily displaced and separated. In these instances the caecal mass assumes a mosaic appearance. While this is generally confined to the left margin and apex, or occasionally extends over the left half of the organ, it is quite similar to the condition found in *E. yaito*. The semblance is heightened when it is associated with a deposit of fat on the ventral wall of the stomach, or along the intestinal membrane.

Liver

The liver consists of three lobes. As in all species of this genus the right lobe is by far the longest. The center and left lobes are approximately equal in length. The right lobe is flat and in its proximal extent lies dorsal to the remaining viscera. From this dorsal origin on the right side, it extends posteriorly and ventrally, and thus comes to lie on the right ventral face of the remaining viscera. This lobe extends almost the full length of the body cavity. Though extensive, the three lobes are thin and lack depth.

Conspicuous hepatic veins run the length of all lobes on the ventral surface, as in all members of *Euthynnus* and *Auxis*. A branch of the coeliac mesenteric artery accompanies each vein but this is apparent only in injected specimens.

The excised liver is illustrated in Figure 58, which shows the relative length of the three lobes. Lobules of liver tissue project profusely from the head of the liver, the majority going dorsally between adjacent organs. A peculiarity of this genus is illustrated in this figure. The anterior end of the gall bladder is recessed between the lateral margin of the right lobe proper and a projecting lobule from this lobe, so that the head of the gall bladder lies in a deep cleft in the substance of this lobe. This character was noted in all specimens examined for this structure.

FIGURE 58. Black skipjack: Ventral view of the excised liver. The gall bladder is shown with the head enclosed in the characteristic cleft in the margin of the right lobe.

Stomach

The stomach covers almost the full length of the body cavity, and is equally extensive in small and large specimens. No particular observations of this organ were made.

Intestine

The duodenum opens through the pylorus into the stomach on the left side of the fish far anteriorly as in the tunas. It runs transversely and anteriorly as a folded, thin-walled expanded tube to the extreme anterior end of the body cavity on the right side. The caecal ducts, of which there are approximately seven, open into the duodenum along its entire extent. Six of them enter the posterior edge of the duodenum and one the anterior edge. Reaching the anterior extremity of the body cavity on the right side, the duodenum becomes constricted, and as the small intestine, it turns posteriorly and runs directly to the vent, without a fold or convultions, thus conforming to the pattern throughout the Katsuwonidae.

Spleen

FIGURE 59. Black skipjack: Ventral view of the excised spleen. In shape the spleen tapers from the thickened, shaded edge. It is invariably elongated but highly variable in outline.

The spleen is perhaps the most perishable of the visceral organs and can be removed intact only in fresh or promptly frozen specimens. The excised spleen is a small club-shaped organ with the widest portion anteriorly, tapering to a blunt point posteriorly. It is relatively thin on one edge, but of appreciable depth along the opposite edge. The shape is highly variable and may depart conspicuously from that portrayed in Figure 59. It is relatively small, even in large specimens. *In situ*, the spleen is entirely hidden in ventral view by liver and caecal mass, as it is located at the extreme anterior end of the body cavity, enclosed between the right dorsolateral face of the stomach and the body wall.

Gall Bladder

Typically, the gall bladder lies on the dorsal surface of the right lobe of the liver, covering the central portion of this lobe, and is therefore not seen in ventral view of the viscera. The anterior end of the gall bladder is recessed into a fork of the liver tissue (Figure 58). This cleft is on the distal (or dorsal) margin of the lobe and hence lies against the body wall and is hidden in ventral view. The anterior end of the gall bladder tapers abruptly into the bile duct which runs on the dorsal face of the right lobe of the liver. In fresh specimens the gall bladder is a bright green.

Air Bladder

There is no air bladder in this species.

Excretory System

Kidney

The kidney is extremely long and extends approximately the full length of the body cavity. Posteriorly the kidney is a wedge or narrow, tapered tongue of tissue in the mid-dorsal wall of the body cavity, reaching generally to the anterior tip of the urinary bladder, which is below the 21st or 22d vertebra. Anteriorly, the kidney expands in the pectoral region into the lateral walls of the body cavity, but this and the anterior portion were not investigated. The margins of the kidney are not sharply defined. They may be relatively straight, with slight periodic indentations, or regularly crenulated as in Figure 60. The ventral wall of the postcardinal vein can be seen on the surface of the kidney in the mid-line.

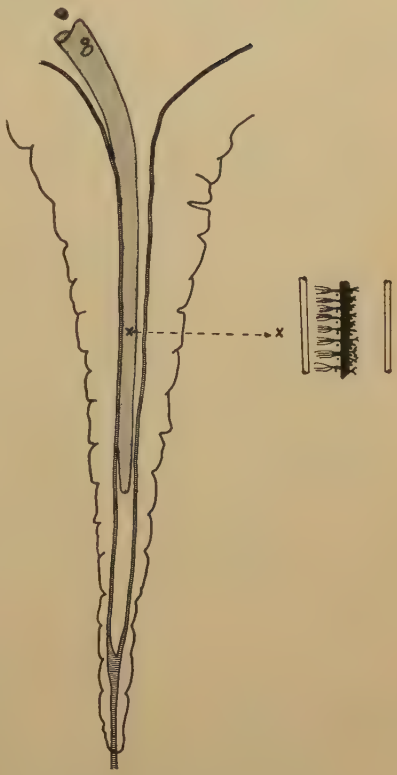

FIGURE 60. Black skipjack: The posterior kidney mass and the course of the ureter. The postcardinal vein separates the two branches of the ureter. The sketch at right is an enlargement of the section at X, with the wall of the postcardinal opened. This view depicts the injected dorsal aorta which thus shows in the dorsal wall of the postcardinal. The lateral rows of arterioles are illustrated and between arterioles are the apertures of the accompanying venules discharging into the postcardinal.

Ureters

The trunk of the ureter joins the urinary bladder at its anterior tip. It runs within the dorsal wall of the bladder a distance of two or more millimeters, however (in an adult specimen), as in the tunas, before opening through an internal aperture. Proceeding anteriorly, the ureter passes through the peritoneum and can be followed along the mid-dorsal line into the substance of the kidney. At some point between the posterior extremity of the kidney and the first completed haemal arch through which the postcardinal vein emerges, the two branches of the ureter converge to form the single posterior trunk. The extremes encountered in this point of convergence correspond to positions between the 18th and 21st vertebrae. From this point anteriorly, the two branches run parallel and separated by only a few millimeters. Meeting the postcardinal vein as that emerges from the haemal canal the branches of the ureter continue anteriorly separated by this vein. The branch on the right side is closely associated with, and in places adherent to, the wall of the postcardinal, but the left branch appears to be removed by 1 to 3 mm. from the vein. In the pectoral region both branches turn laterally and run

through the anterior expanded portion of the kidney. Beyond this, they were not followed. The right branch follows the curvature of the post-cardinal vein, while the left branch duplicates this course on its own side.

The ureters in this species appeared initially different from those of *alletteratus*. In *lineatus* the two branches of the ureter are large and straight. In *alletteratus* they are frequently small and somewhat erratic in their course. However, in at least two of the eight specimens of the latter the branches of the ureter were essentially comparable with and indistinguishable from those of *lineatus* or *yaito*. Hence any actual difference is relative and not diagnostic. It is quite possible that the suggested differences are entirely fortuitous.

Urinary Bladder

The urinary bladder is difficult to locate and observe. It is a thin-walled inconspicuous structure located against the dorsal wall and at the extreme posterior end of the body cavity. It is enclosed between the membranes of the gonads, and is adherent throughout its extent to the dorsal body wall. The aperture of the ureter lies in its dorsal wall, two or more millimeters from its anterior tip in an adult specimen. As in the tunas, the ureter is roofed from the aperture to the tip of the bladder. This aperture, not otherwise apparent, can be found most readily by probing. These observations are essentially similar to those made on other species of *Euthynnus*.

Circulatory System

Anterior Arterial

There is nothing specifically distinct in this system. The cutaneous arteries are sometimes staggered in origin, but because they do arise opposite each other in most specimens, this character will not separate *lineatus* from other species of *Euthynnus*.

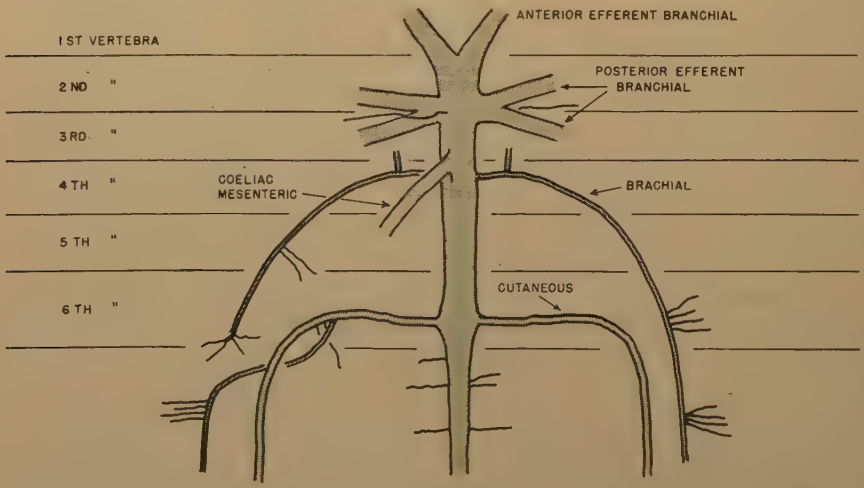

FIGURE 61. Black skipjack: Anterior arterial system. The sketch illustrates the variable origin of the ventral branch of the cutaneous artery. In this specimen it originates in the trunk of the cutaneous artery on the right side, and in the brachial artery on the left side.

The anterior efferent branchials fuse in an acute angle to form the aorta, generally beneath the junction of first and second vertebra. The posterior efferent branchials form short trunks that join the aorta beneath the junction of the second and third vertebra or as often below the third vertebra. The coeliac masenteric artery arises on the right side below the junction of the third and fourth vertebra, or below the anterior half of the fourth vertebra. Brachial arteries arise dorsolaterally just posterior to the coeliac mesenteric, and the customary ligament partially encircling the aorta is found at this point also. The brachial arteries in this species are moderate in size, and proportionately larger than in other members of the genus. The cutaneous arteries arise perpendicular to the aorta, and in the majority of cases the origins are opposite. When staggered, the left branch is anterior to the right and the distance between the origins is quite variable. They invariably arise in the aorta beneath the sixth vertebra. There is no reduction in size of the aorta beyond the origin of the cutaneous, and it continues posteriorly as a large vessel.

Pharyngeal muscles are attached to the sixth vertebra, extending to adjacent portions of the fifth and seventh also.

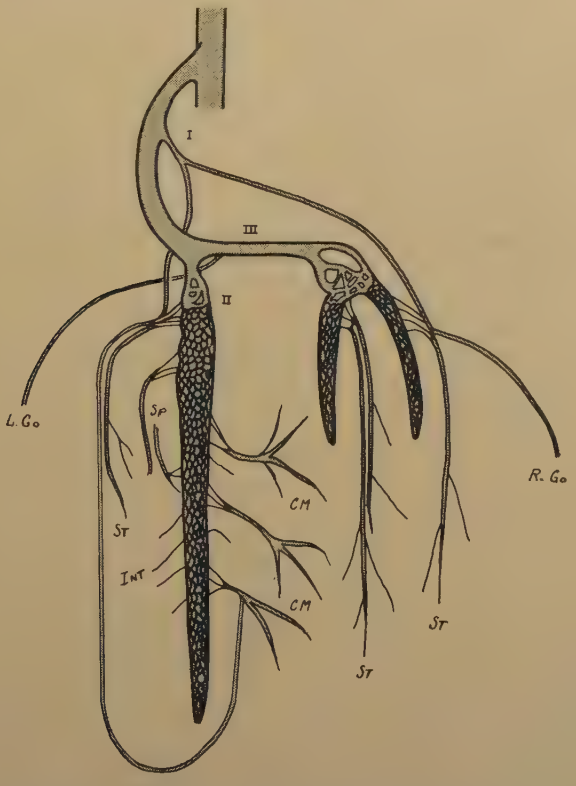

Figure 62. Black skipjack: Diagrammatic sketch of the coeliac mesenteric artery. CM = caecal mass. Int. = intestine. L. Go = left gonad. R. Go = right gonad. Sp = spleen. St = stomach.

Visceral Arterial

The coeliac mesenteric artery originates laterally on the right side in the vicinity of the fourth vertebra. Near its origin (within a half inch of it in adult specimens) it gives off a small branch from its dorsomedian face. This is an abortive or rudimentary No. I branch. Beyond this the coeliac mesenteric trunk continues posteriorly and ventrally for a considerable distance, and it does not divide until it reaches and enters the substance of the liver. In this undivided extent it gives off a few (two to four) minute vessels which run to the walls of the esophagus and to the pericardial septum. Just after the coeliac mesenteric trunk enters the head of the liver, slightly on the right side, it divides into two equal parts. These correspond to the No. II and No. III branches of the Thunnidae. Each of these two branches becomes immediately dispersed into a most astonishingly complex, fine, network that completely envelopes throughout its length that portion or branch of the hepatic portal vein with which it is associated. From these reticulations arise, usually in a multiple origin, the discrete vessels which nourish the remaining organs of the viscera. The existence of these arterial networks makes the initial dissection of this system most confusing. Large and moderate arteries to separate organs become dissipated at both ends and appear to have no origin. The origin, actually, is concealed within the substance of the liver and consists of numerous small strands which arise in the reticulations in the walls of the hepatic veins, and which progressively fuse to form a moderate or large trunk.

The No. I branch is rudimentary. While it is fairly constant in origin, its course is erratic, and its location and small size render difficult an exact determination of its fate. In the majority of specimens examined, the No. I branch goes to the dorsal face of the right lobe of the liver, and there joins the reticulated origin of a large vessel which emerges from the liver to nourish the right dorsolateral wall of the stomach. Thus, in this species the No. I branch is merely a tributary to the No. II branch; whereas in the Thunnidae the No. I branch serves the specific function of nourishing the left dorsolateral wall of the stomach. Actually, a small branch can be found in some specimens of *E. lineatus* coming off the No. I branch and running to the left side in the dorsal wall of the esophagus. This small branch runs to the left anterior wall of the stomach where it joins a larger vessel emerging from the left lobe of the liver and going posteriorly on the left dorsolateral wall of the stomach. Thus the pattern of other tunas in which the No. I branch nourishes the face of the stomach can be seen in an incipient stage. There is in *E. lineatus* a great deal of variation in the vascular pattern. In most instances the supply of arterial blood comes from several sources. Thus in one specimen the No. I branch was connected with an irregular vessel that arose in the aorta on the left side, just posterior to the coeliac mesenteric artery. In several specimens the right gonad received a moderate arterial supply through a branch which originated in the reticulations between the No. I and No. II branches. In some specimens the left gonad received a supply which came in part from the No. I branch. Finally, in one specimen the ventral cutaneous artery on the right side had its origin in the No. I branch of the coeliac mesenteric artery.

The No. II branch is more regular. At its origin dorsal to the right hepatic portal vein it immediately breaks up into a number of moderate vessels encompassing the wall of this vein. The identity of individual vessels is immediately lost in the network that is formed by the prolific breaking up and anastomosing of branches. The right hepatic vein is literally enmeshed throughout its length in the right lobe of the liver by this arterial reticulation which is diagrammatically illustrated in Figure 62. This is one of the most striking characteristics of *Euthynnus*.

From multiple origins in this network arise separate vessels to the right dorsal wall of the stomach, to the spleen, caecal mass, gall bladder and intestine. The right dorsolateral wall of the stomach is generally nourished by a pair (sometimes a trio) of arteries which run parallel and together. These vessels originate in anastomosing strands emerging from the head of the right lobe, and in a small vessel from the No. I branch. They are the first trunks to emerge from this lobe. In maturing specimens the right gonad receives a moderate branch which frequently arises in this complex. One of the two vessels on the dorsolateral wall of the stomach ends in terminal branches in the mid-length of the stomach. The other continues to the posterior tip of the stomach. Here it leaves the stomach and crossing in the mesentery it appears to be connected and continuous with a large vessel coming from the right lobe of the liver and supplying the dorsal face of the caecal mass. Sometimes this junction is on the face of the caecal mass, while in other specimens the vessels join in the substance of the right lobe of the liver. However these vessels join, the existence of the connection is a striking characteristic of the genus. In the ventral view of the viscera, *in situ*, of an injected specimen, this arterial loop at the tip of the stomach is conspicuous and confusing.

Arising similarly with the above vessels to the right lateral wall of the stomach is another moderate vessel which runs to the anterior end of the spleen, ramifying throughout its anterior substance. A short distance posterior to this another vessel, originating in the hepatic arterial network, emerges from the right lobe and runs to the posterior portion of the spleen. Beyond this, two or more vessels emerge from the right lobe of the liver and cross to the adherent caecal mass, where they branch profusely, and disperse over the dorsal surface. The posterior vessel of this series is the one contributing to the arterial loop described above. From this loop originate several small vessels which go to the walls of the rectum.

Throughout the length of the right lobe of the liver innumerable small vessels emerge from its substance to nourish the intestine, the gall bladder and anteriorly the caecal mass.

The No. III branch, from its origin at the right hepatic portal vein, continues to the left hepatic portal vein. In this extent it gives rise to several small vessels which nourish the adjacent liver tissue. Reaching the left hepatic portal vein the No. III branch divides into at least two equal vessels. One goes transversely dorsal to the vein and the other ventral to it. Each of these branches may divide, and both invariably disintegrate into two networks comparable with that of the No. II branch, which in this case enmesh the walls of the hepatic veins run-

ning respectively in the center and left lobes of the liver. From these reticulations arise the individual vessels nourishing other organs.

From the head of the liver or from the center lobe emerge two large vessels. These vessels run posteriorly on the dorsal face of the caecal mass into which they send numerous radiating branches. The trunks leave the caecal mass in the vicinity of the pylorus and cross in the mesentery to the ventral wall of the stomach. One of these two vessels terminates about the mid-length of the stomach while the second runs to its posterior tip. Associated with the latter in some specimens is an attenuated, diffuse and finely lobulated mass of tissue in the membrane enveloping the stomach. This tissue is creamy in color and was adjudged to be fat. It suggests a rudimentary or incipient fat organ such as is found in other species.

From the dorsal face of the left lobe of the liver emerge two or three small arterial strands that originate in the network within this lobe. These strands run to the anterior left wall of the stomach. Variation in their specific course is excessive, but the underlying pattern appears to be a system that supplies blood to the left dorsolateral wall of the stomach and to the left gonad. This supply is indirect in the sense that it comes from an anastomosing of vessels with different origins. Thus one of the two or three strands under discussion is connected with the small No. I branch and sometimes directly with the dorsal aorta.

Associated with this complex is a vessel which runs to the left gonad. In some specimens this appears to come from the No. I branch, but in most, its origin is complex and derived in part from both the No. I and that portion of the No. III branch nourishing the left dorsolateral wall of the stomach. The right gonad receives a supply which comes in some specimens either directly from the No. III branch near its origin or from the trunk of the coeliac mesenteric before its division. In other specimens this vessel originates in the anastomosing of those vessels emerging from the head of the right lobe of the liver. In occasional specimens the No. I branch sends a direct supply to the right gonad. In addition to this supply the gonads, in their median and posterior extent, receive a series of segmental vessels from the axial system, one of which is conspicuously larger than the rest.

The above is an attempt to describe the prevailing pattern of the coeliac mesenteric artery. The essential characteristics of this are a small and erratic No. I branch arising near the origin of this artery; a late division of the main trunk into a No. II and No. III branch; the disintegration of both branches into remarkable complex networks completely enveloping the walls of the hepatic veins; the origin of separate visceral vessels from strands of this reticulation and finally the peculiar arterial loop at the tip of the stomach. Variation is excessive, suggesting instability in the visceral circulatory pattern. No essential differences in this system were detected to differentiate *lineatus* from either *yaito* or *alletteratus*. The peculiarities are generic.

Cutaneous System

The cutaneous system in this species is essentially similar to that of the other species in this genus. In the majority of specimens the cutaneous arteries arise opposite one another in and approximately per-

pendicular to the aorta beneath the sixth vertebra and run laterally through the kidney tissue. The extent of variation in their point of origin ranged from the junction of the fifth and sixth vertebrae to the anterior end of the seventh vertebra. Occasionally the origins are staggered, and in such cases the left is generally anterior to the right. Each artery passes generally between the first and second ribs, but occasionally between the second and third ribs. It is not uncommon to find the two sides of one fish differing in this respect. Just before reaching the ribs each artery may give off a small to moderate vessel which becomes the ventral branch of the cutaneous artery. This will be described later. The trunk of the cutaneous artery, which from this point becomes the dorsal branch, continues laterally and passes in most cases between the third and fourth intermuscular bones to reach the surface musculature. In this respect it is quite variable, however, and the artery may pass between the first and second intermuscular bones at one extreme, or between the fourth and fifth intermuscular bones at the other extreme. This is an unsatisfactory character because of the difficulty in locating positively the short first intermuscular bone. From this point the artery runs posteriorly in the surface musculature just beneath the skin in a relatively straight line, ending in terminal branches in the surface muscles of the caudal region.

The dorsal cutaneous vein runs with and adherent to the artery throughout its course on the surface. In this extent it is ventral to the artery as in all species of this genus. Just before traversing the intermuscular bones on its course axially, the vein crosses the external face of the artery and runs axially dorsal and slightly anterior to the artery. The connection of the dorsal cutaneous veins with the axial venous system was not established. Approaching the Cuvierian ducts the cutaneous veins appear to break up in the substance of the kidney, and no direct connection with either the postcardinal vein or the Cuvierian ducts was seen.

Both vein and artery are associated with segmental vessels throughout their course on the surface, and these segmentals run both dorsal and ventral to the cutaneous vessels. The dorsal segmentals are regular and parallel in course, each curving posteriorly. However, long and prominent dorsal segmental arteries alternate with short and inconspicuous ones. The pattern is fairly regular, though one finds exceptions in individual segments. The dorsal segmental veins in most cases cross the outer face of the artery. The relation of the vein to the artery within a segment is variable. The artery may lie anterior or posterior to the vein (always adherent) and frequently the vein is sandwiched between the divided artery.

The ventral segmentals are more irregular in course and origin. From their origin in the dorsal cutaneous branch they run posteroventrally for a short distance (roughly half an inch) and then turn in an obtuse angle to run anteroventrally. Beyond this their course is irregular and branched. The ventral segmentals are most conspicuous anteriorly. Posteriorly the venous segmentals appear to play the major role, because their course can be plainly seen, whereas the arteries, even though injected, were small and insignificant in the caudal region. The ventral segmental arteries at their origin generally but not invariably cross the mesial face of the cutaneous vein.

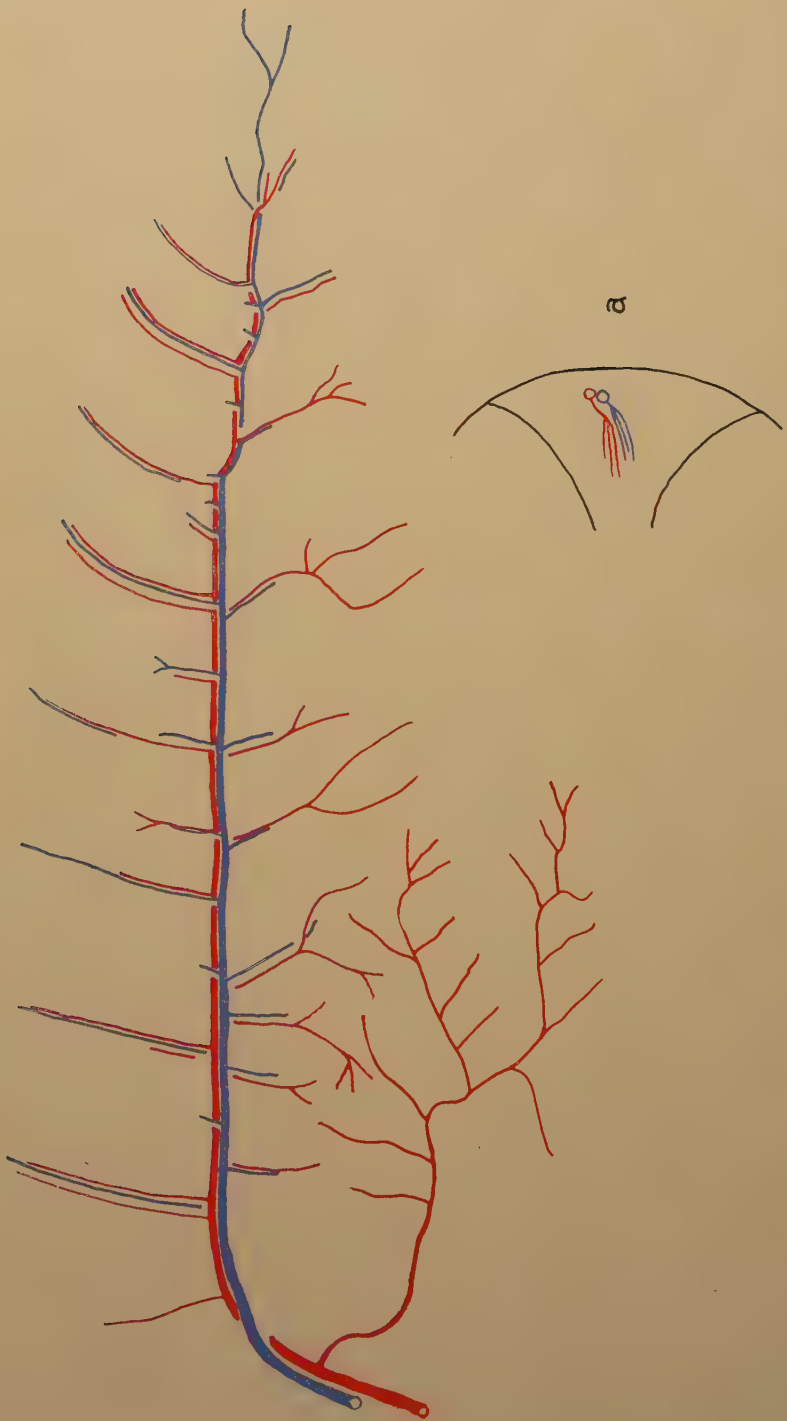

FIGURE 63. Black skipjack: Cutaneous system. *a* shows the origin of venules and arterioles

Both vein and artery are associated with capillary sheets throughout their length beneath the skin. Arterioles arise in a single, irregular row from the proximal-axial face of the artery. This row may be fairly continuous, or it may be interrupted by short interspaces in which there are no arterioles. In occasional specimens the arterioles are sparse. Within two or three millimeters of its origin each arteriole divides and thereafter immediately breaks up into a capillary sheet. Contiguous sheets merge and run axially into the blood meat of the lateral line, in several planes.

Similarly an irregular row of venules enter the axial face of the vein. There appears to be some disagreement in the notes of individual dissections as to the precise arrangement of these venules. In some cases the notes state that venules join the axial face of the vein, more or less apposed to the arterioles. In others they are recorded as joining the proximal-axial face of the vein. It is possible that this difference is either interpretative or that some variation exists in their exact location. Probably it is both interpretative and variable. The venules definitely enter the mesial (axial) face of the vein. Beyond this, no significance should be attached at present to a more precise specification of their point of entry.

These venules are derived from capillary sheets, which, with similar arterial capillaries, permeate the blood-meat of the lateral musculature. In some specimens these capillary sheets are continuous, becoming sparser posteriorly. In others these sheets are discontinuous, with spaces up to one-half inch without capillary origins. In the above respects this description would fit any described species of the genus.

The ventral cutaneous artery appeared to be larger and more developed in this species than in others of the genus. However, if this impression should subsequently prove to be correct, the difference is relative and of no diagnostic value. The origin of the ventral cutaneous artery is erratic. It arises in the trunk of the cutaneous artery, or in the brachial artery or occasionally in both. Typically, the ventral branches arise on each side from the cutaneous artery just before that vessel reaches the ribs. From its origin the ventral cutaneous branch runs ventrally in the kidney tissue towards the pectoral fin. On its path towards the surface it passes anterior to the first rib, and continues ventrally to the location of the ventral extremity of the pectoral insertion. At this point the artery turns posteriorly at right angles and emerges in the surface musculature at the base of the pectoral fin. It regularly gives off one or more minute branches which apparently run to the ventral extremity of the pectoral insertion, and in some specimens similar small vessels were seen running to the dorsal extremity of the pectoral insertion. In the surface musculature the ventral cutaneous artery gives rise to a short branching system of vessels nourishing the ventral musculature in the pectoral region (Figure 63).

At its proximal end the ventral cutaneous artery gives off, within the substance of the kidney, numerous minute strands which nourish both the adjacent kidney tissue and the walls of the postcardinal vein and the Cuvierian duct. In some specimens similar strands (which may be appreciable in size) originate in the cutaneous trunk itself and run into the kidney tissue. In occasional specimens the ventral cutaneous artery may divide at its origin into two or three parallel strands which

anastomose freely. These parallel strands may subsequently fuse, or they may run separately to the surface and contribute a constituent part of the surface system.

While the foregoing may be considered as a typical pattern in this species, the majority of specimens will manifest detailed departures from it. The most significant and consistent variation is in the origin of the ventral branch. Not only is this variable from fish to fish, but frequently the two sides of the same fish differ. In such cases the ventral branch of the cutaneous artery arises normally on one side, in the cutaneous trunk, while the mate to it on the other side arises most frequently in the brachial. In one extreme case this branch actually originated in the trunk of the coeliac mesenteric artery.

The brachial artery, when it gives rise to the ventral cutaneous artery, is otherwise normal in course. It originates in the dorsal aorta, invariably just posterior to the origin of the coeliac mesenteric artery. It runs laterally, perpendicular to the aorta, sometimes inclined anteriorly. Roughly one-fourth inch beyond its origin it divides into its two invariable major components. One runs anteriorly towards the skull at right angles to its preceding path. The other continues laterally through the kidney tissue and curves gradually posteriorly and ventrally towards the pectoral insertion. In this course it gives rise to numerous small strands which nourish the kidney. In the vicinity of the postclavicle the brachial normally turns laterally and disappears into the bones of the pectoral girdle. In those specimens in which the brachial becomes the ventral cutaneous it branches at this point. The minor branch follows the normal course as the brachial, while the major portion continues posteriorly and emerges at the base of the pectoral fin in the surface musculature as the ventral cutaneous artery. In occasional specimens both the brachial and the cutaneous arteries contribute to the formation of the ventral cutaneous branch. No two specimens are quite alike. It is of interest to note that Kishinouye likewise encountered this variation and defines it as a rare abnormality.

The ventral cutaneous vein was injected and observed in only one specimen. In this case it duplicated the course of the corresponding artery and was adherent and dorsal to the artery. Entering the kidney substance in its course towards the heart the ventral cutaneous vein expands into a funnel, which appears to disintegrate into numerous vascular passages through the kidney.

The cutaneous system in this species is indistinguishable in pattern from that of *alletteratus* and *yaito*. It differs biometrically in two minor respects. The cutaneous trunks of *lineatus* pass predominantly between the first and second ribs, whereas in *E. yaito* they pass between the third and fourth ribs in the majority of specimens. In *alletteratus* they pass invariably (both sides of eight specimens) between the first and second ribs. Hence, on the basis of this character, *lineatus* can be separated collectively but not individually from *yaito*, but not from *alletteratus*.

There is also a suggestive difference between *lineatus* and *yaito* in the course of the cutaneous vessels between the intermuscular bones. However there is too much uncertainty in the count of these bones to place

any significance in this result. The first and sometimes the second intermuscular bones are frequently very short, and the first (and occasionally the second) bone is so intimately associated with the skull that it can be readily overlooked. This has undoubtedly occurred in some of the present data. The count of the ribs, however, is precise.

Postcardinal Vein

The postcardinal vein is a large conspicuous vessel comparable in structure and position with that of all members of this family. It emerges from the haemal canal through the first completed haemal arch, and runs anteriorly in the mid-line within the substance of the kidney. Its ventral wall is exposed at the surface of the kidney. Approaching the heart it curves to the right, and empties directly into the right Cuvierian duct.

The dorsal aorta runs in, or adherent to, its dorsal wall, and in an arterially injected specimen can be seen in its dorsal wall. When the ventral wall of the postcardinal is open in such a specimen and its interior exposed, a beautiful system of arterial capillaries is revealed. These originate, in an adult specimen, as arterioles in each lateral margin of the aorta, at distances of not more than one-eighth inch apart, and immediately break up into capillary bundles that nourish both the adjacent kidney tissue and the lateral walls of the postcardinal vein. This condition is illustrated in Figure 60.

Between successive arterioles is an aperture in the dorsolateral wall of the postcardinal vein. Each such aperture is apparently the orifice of an entering venule which serves, either the kidney tissue or the dark meat immediately ventral to the spinal column. (These vessels were not injected.) Thus throughout this extent of the postcardinal vein its lateral walls are enmeshed with arterial capillaries, between the origins of which run venules from the dorsal muscles.

The foregoing description could apply to any species of this genus. Hence it is not specifically diagnostic.

FIGURE 64. *Euthynnus yaito*: Specimen taken August 1948, Hawaiian Islands. *(Photo by Al Johns for Vernon M. Haden, San Pedro.)*

HAWAIIAN BLACK SKIPJACK (*Euthynnus yaito*)

This description is based upon a total of eight specimens. Four of these were collected by the writer in the summer of 1948, while on a research cruise aboard the N. B. Scofield in Hawaiian waters. These specimens were subsequently dissected by Messrs. E. K. Holmberg and E. C. Greenhood and the notes and drawings placed on file. Early in 1953 the writer obtained through the courtesy of the staff of Pacific Oceanic Fisheries Investigations four additional specimens. These were dissected and furnish the essential basis of this description. The origins of the specimens, as far as known, are listed below. Because innumerable specimens of *E. yaito* were taken during the 1948 cruise the precise origin of these particular specimens is not known. All however, came from the region of the Hawaiian archipelago between French Frigate Shoals and Honolulu.

Specimen No.	*Date caught*	*Locality of capture*
No. 1	August, 1948	Probably off Necker Island, or between Necker Island and Nihoa Island, T. H.
No. 2	August, 1948	
No. 3	August, 1948	
No. 4	August, 1948	
No. 5	February 11, 1953	10 miles off Ewa, Oahu, T. H.
No. 6	February 11, 1953	10 miles off Ewa, Oahu, T. H.
No. 7	January 26, 1953	Off Honolulu
No. 8	February 1, 1953	7 miles off Honolulu

EXTERNAL CHARACTERS

This species can be readily assigned to family and genera by its superficial appearance. The form, the finlets and the pattern of dorsal markings channel it into the Katsuwonidae, while the contiguous dorsal fins and the dorsal markings place it in *Euthynnus*. The superficial identification of the species is more difficult. While the dorsal markings will separate *E. yaito* from a typical specimen of *E. lineatus*, they will not separate the former either from the extreme variants of *lineatus*, or from all specimens of *E. alletteratus*. The presence of vomerine teeth in *E. yaito* will generally serve to distinguish it from *E. alletteratus*, which lacks them. Supplemented by the gill raker count (total count of 29 to 33 in *E. yaito* compared with 33 to 37 in *lineatus* and 37 to 40 in *alletteratus*) the above differences will serve as a tentative diagnosis of this species. A discussion of the positive identification will be deferred until later.

The pattern of dorsal markings in *E. yaito* is distinctive in the majority of specimens. The black bars are more oblique than in the other two species. In reality there is an unbroken integration between the relatively horizontal continuous stripes of the typical *E. lineatus* at one extreme, through the broken, irregular horizontal stripes of *E. alletteratus* to the wavy, oblique markings of *E. yaito* at the other extreme. Any typical specimen of any one of these species could be identified by its markings, but the latter would most certainly fail to identify a variant. Thus, in one specimen of *E. yaito* the markings

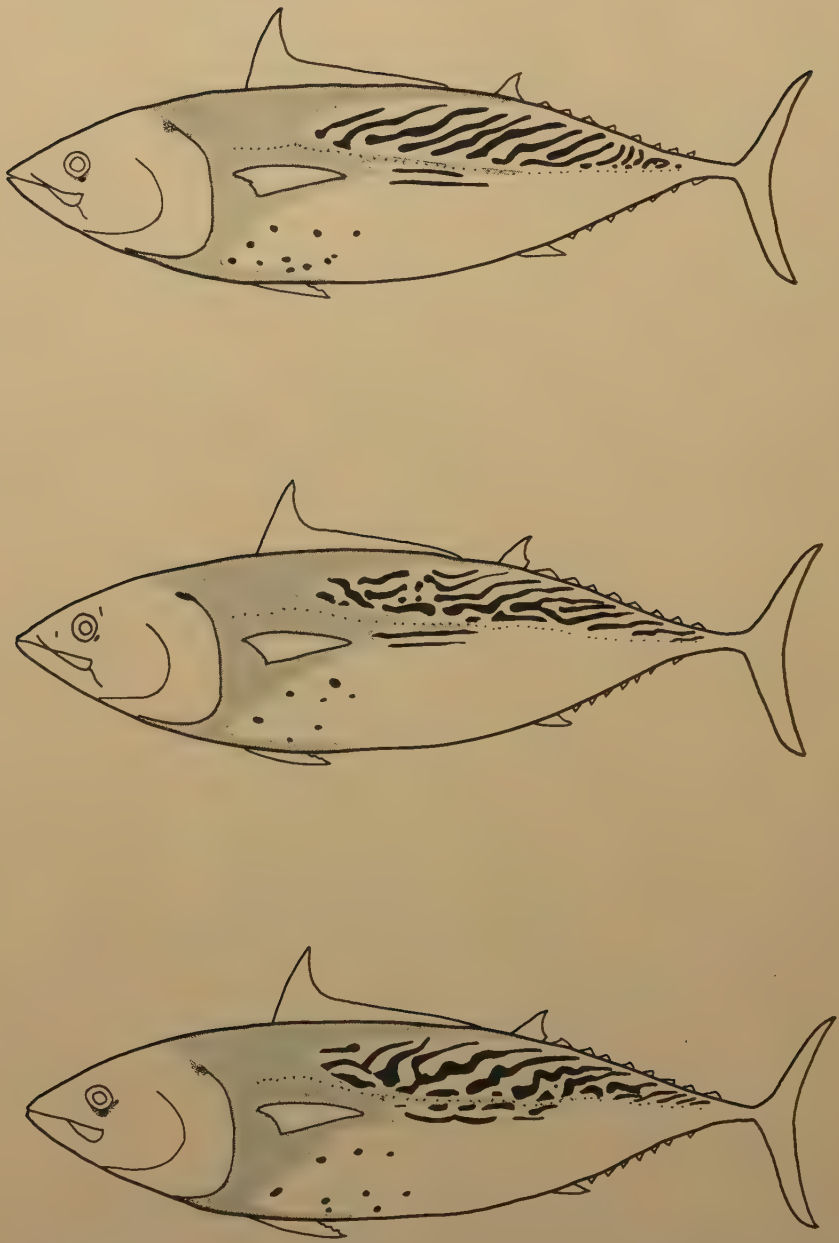

FIGURE 65. *E. yaito*: Variations in the markings of three specimens

closely approached those portrayed for *E. alletteratus aurolitoralis,* Fraser-Brunner, 1949, from the Gold Coast, which appears to constitute an extreme of marking. Despite statements in the literature to the contrary, the dorsal markings are extremely variable and do not constitute a positive diagnostic character. Figure 65 illustrates the markings of *E. yaito.*

The above pattern is superimposed upon a blue to indigo background which is most accentuated in the anterior region. On the belly below the pectoral there are a number of black or dusky spots, scattered over a relatively wide area. They are variable in number, position and extent, and cannot be regarded as a specific character. In a direct comparison of a series of *E. lineatus* and *E. yaito* the spots on the latter appeared distinctly smaller.

The lateral line differs relatively from that of *E. lineatus* and *E. alletteratus.* In *E. yaito* the crest or rise above the pectoral is at a minimum, and in many cases the lateral line runs almost horizontally from the margin of the opercle, over the anterior third of the pectoral where it slopes gently downward. When a rise is present the anterior slope is always gentle, never abrupt as in extreme cases of *lineatus.* Posteriorly, the lateral line is regular and free of conspicuous undulations. The dip below the second dorsal which characterizes many specimens of *E. lineatus* is absent or inconsequential. In those specimens examined the lateral line was relatively more prominent and conspicuous in *E. yaito* than in *E. lineatus,* with *E. alletteratus* occupying a transitional position.

It appeared as though the corselet of *E. yaito* differed relatively from that of *E. alletteratus.* The posterior bulge or projection adjacent to the tip of the pectoral appeared longer in most specimens of *E. yaito* than in *E. alletteratus,* but measurements on subsequent specimens revealed that this was quite variable and lacked specific significance.

As in other species of this genus the caudal keels are not conspicuously developed and are evidenced externally only by a dorsoventral flattening of the peduncle.

The posterior margin of the operculum is relatively straight. At the dorsal extremity of this margin there is generally a small dark or black elongated spot. The preoperculum is gently and smoothly rounded in posterior outline, as in the other species of this genus. There is a small irregular dark spot or area below the posteroventral margin of the eye.

The maxillary extends to or slightly beyond the vertical through the middle of the eye. While it definitely extends more posteriorly, in relation to the eye, than in the other species of *Euthynnus,* the difference is relative and the character is not one to justify a positive identification. In some cases the description of a specimen of *E. yaito* would fit that of *E. lineatus.* The teeth are moderate in size and comparable with those of *E. lineatus* and *E. alletteratus.* There are from 24 to 35 teeth on each side of the lower jaw, depending upon the size of the specimen. The smallest number occurred on the smallest fish and the greatest on the largest fish. Vomerine teeth were invariably sharp and obvious to the touch, but palatine teeth, though present in all, were prominent in about half the specimens. The tongue has a lateral cartilaginous ridge projecting dorsally on each margin as in other members of the genus. The degree of development of these ridges was variable.

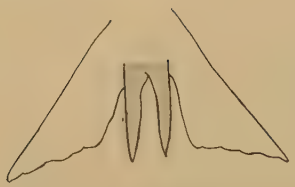

FIGURE 66. *E. yaito*: Typical appearance of interplevic process

The interpelvic processes were divided in all specimens as illustrated in Figure 66, but frequently one process was longer than the other.

The dorsal fins are contiguous and the first dorsal is high, being about twice the height of the second dorsal fin and roughly half the head length. The first two rays of the first dorsal are roughly equal in length, and succeeding rays are progressively and appreciably shorter so that the dorsal outline of the fin is strongly concave. The anal fin is inserted on a vertical through the origin of the first dorsal finlet, or between this and the end of the second dorsal base. There were eight dorsal and seven anal finlets in all specimens. The plaque of scales surrounding the ventral fins extends from one to two centimeters in fish of 40 to 60 cm. body length posterior to the tip of the ventral fins.

Gill rakers are fully developed on the first arch only. There is invariably a raker at the angle of the arch with a basal process extending both dorsally and ventrally. On subsequent arches there may be occasional and scattered rakers. Thus in one specimen there were two short stubby rakers at the angle of the second arch, and one such raker at the angle of the third arch. Moreover, on the upper limb of the third and fourth arches there were respectively three and five such short stubby rakers. The raker count (first arch, left side) was 7(7-9) + 1 + 24 (22-24) = 32 (29-34).

Gill teeth, or posterior rakers, are present on all arches. They are most developed on the first arch, on which the modal count was 8 + 20 = 28, with a variation in total count ranging only from 27 to 29 (seven specimens). On the first arch the longest teeth measured roughly nine mm., while the longest tooth on the last arch was roughly three mm.

PROPORTIONAL MEASUREMENTS

The measurements taken are tabulated in Table 12. Discussion of these is reserved for a subsequent comparative section.

A simultaneous comparison of specimens of *E. yaito* with *E. alletteratus* and *E. lineatus* late in this study suggested that the width of the fleshy interorbital was greater in *E. yaito* than the distance of the eye from the snout; whereas in *alletteratus* and in *lineatus* it appeared less. Precise measurements were difficult to obtain, but the following approximations confirmed this impression.

	Width	*Length*
E. yaito, No. 6	36 mm.	35 mm.
E. yaito, No. 7	61.5 mm.	57 mm.
E. alletteratus, No. 7	51 mm.	55 mm.
E. lineatus, No. 28	35 mm.	40 mm.

The width is defined as the width of the fleshy interorbital through the anterior margin of the eye; and the length as the distance along the mid-dorsal line of the head from the tip of the snout to the inter-

TABLE 12

Euthynnus yaito: The Measurements Made Upon Eight Specimens, and the Range in the Resulting Ratios, of Which Body Length Is the Numerator in Each Case Except Those Indicated by an Asterisk. In the Latter the Head Length Becomes the Numerator.

	Fish number								
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	Ratios
Body length	617	629	617	590	378	382	643	629	
Head length	176	176	172	165	105	109	187	179	3.44– 3.60
1st dorsal insertion	191	195	192	183	120	123	205	199	3.11– 3.23
2d dorsal insertion	373	375	369	354	223	230	388	381	1.65– 1.70
Anal insertion	417	416	407	387	250	258	435	425	1.48– 1.52
Ventral insertion	201	194	193	185	118	122	205	201	3.07– 3.24
Greatest body depth	163	177	159	148	95	97	164	166	3.55– 3.99
Greatest body width	112	119	112	104	ca 58	64	122	----	5.27– 5.97
Dorsal-ventral distance	156	163	153	141	92	94	158	158	3.86– 4.18
Dorsal-anal distance	267	276	269	248	160	166	276	267	2.28– 2.38
Ventral insertion to vent	220	220	211	200	132	135	227	229	2.75– 2.95
Length 1st dorsal base	191	192	191	180	107	112	191	188	3.23– 3.53
Length 2d dorsal base	40	44	43	38	26	25	42	41	14.29–15.53
Length of anal base	39	42	44	40	23	22	37	39	14.02–17.38
Pectoral length	102	107	107	98	65	65	116	110	5.54– 6.05
Height of 1st dorsal	91	ca 96	ca 103	92	54	55	94	93	6.41– 7.00
Height of 2d dorsal	51	52	Broken	Broken	27	27	53	50	12.10–14.15
Height of anal	----	----	----	----	27	27	54	52	11.91–14.15
Diameter of iris	24	22	25	23	17	18	25.5	23	*6.06– 8.00
Maxillary length	70	71	70	66	45.5	47	77	74	*2.31– 2.51
Snout to posterior margin of eye	----	----	----	----	----	51	80	----	*2.14– 2.34

TABLE 13

Euthynnus yaito: Meristic Counts Made Upon Eight Specimens

	Fish number							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
1st dorsal rays	15	14	14	15	14	15	15	15
2d dorsal rays	13	13	13	12	13	13	13	12
Dorsal finlets	8	8	8	8	8	8	8	8
Anal rays	14	14	14	14	13	14	13	13
Anal finlets	7	7	7	7	7	7	7	7
Gill rakers:								
Upper limb	7	9	7	7	7	8	7	7
Angle	--	1	--	1	1	1	1	1
Lower limb	22	24	24	22	24	23	24	24
Total count	29	34	31	30	32	32	32	32

section with the above line measuring the interorbital width. Both are straight line distances. Because of unsatisfactory reference points leading to excessive error, this suggestive difference was not further investigated.

MERISTIC COUNTS

The data collected from these specimens are shown in Table 13.

INTERNAL ANATOMY

Viscera

The ventral view of the viscera, *in situ*, follows the generic pattern. While there are specific differences, these are not constant, and will not serve as positive diagnostic characters.

The caecal mass occupies the anterior two-thirds of the body cavity, and posterior to this the stomach extends on the left side, the intestine and right lobe of the liver on the right, while in specimens with large

FIGURE 67. *E. yaito*: Ventral view of the viscera, *in situ*, in a large (left) and a small (right) specimen

gonads the latter fill up the marginal outline of the body cavity. In this species the gall bladder is rarely seen in ventral view. Superimposed upon the anterior extremity of the caecal mass are the center and left lobes of the liver. Although extensive, they are frequently inconspicuous because their color and texture blend into that of the caecal mass so that the individual outlines are not readily apparent.

The most striking characteristic of the viscera of *E. yaito* is manifested in varying degree by a majority of specimens. The ventral view conveys the impression of an extensive mosaic. The caecal mass, the lobes of the liver and a posterior accretion of fatty tissue yet to be described are composed of innumerable integrated cells or blocks of varying size, the aggregate of which constitute the respective organs. Because these three organs are contiguous and because the color of all is similar, the visual identity of each is lost in the mosaic of the whole. In extreme cases the viscera appear in ventral view to consist of a solid mass of relatively homogeneous tissue, made up of a myriad of individual cells grouped into a few larger units, differentiated only by slight intergradations of color and texture. While this character is shown in varying degree by the majority of specimens it may, in occasional specimens, be entirely lacking or inconspicuous.

Contributing to the above appearance is an accumulation of fat which is equally characteristic of this species. This is described as fat, without proof of its actual composition. It is creamy in color, often tinged with pink, and is reminiscent of a similar structure found in *Thunnus germo* and in the Pacific mackerel. It appears to result from a proliferation of the fatty tissue commonly found sparsely distributed in the membranes of many of the tuna-like fishes I have examined. In certain species large amounts of such tissue seem to develop in characteristic places and assume a characteristic shape, as a more or less separate organ.

In *E. yaito* the fatty tissue is divided into two aggregates. The larger and more extensive mass forms in the mesentery enveloping, and ventral to, the stomach. While concentrated in the vicinity of the posterior end of the stomach, it is not confined to this region, but extends anteriorly as a diminishing sheet dorsal to the caecal mass. It is composed of myriads of small individual contiguous cells or blocks, and enhances the mosaic effect described for the caecal mass. In fact the two organs are distinguishable only with difficulty.

A second and smaller cord-like aggregation of fat lies in the mesentery enclosing the straight intestine. It is most obvious in the posterior region where the intestine is exposed in ventral view, but extends a variable distance anteriorly, and frequently continues beyond the margins of the caecal mass. The aggregation is much less extensive than that on the stomach, and is confined to the immediate vicinity of the straight intestine. However it is frequently not visually separable from the larger mass on the stomach.

The presence of this fatty tissue is not diagnostic because in some specimens of *yaito* it was absent. Moreover, occasional specimens of *lineatus* showed a similar development although this was never comparable with that in *yaito*.

Minor but variable differences in this view distinguish the average specimen of *E. yaito* from *E. alletteratus* and *E. lineatus*. In *E. yaito* the gall bladder is invariably concealed beneath the right lobe of the liver, whereas in the other species a portion of the gall bladder often shows in ventral view. The location of the right lobe of the liver in *E. yaito* is more comparable with *E. lineatus* than with *E. alletteratus*. In the last species this lobe invariably lies on or near the center line so that its entire ventral surface is exposed. In *E. lineatus* and in *E. yaito* the right lobe of the liver is more lateral in this view, lying against the lateral body wall, so that only its margin is seen. This may not be of any significance, because in most of the specimens of *alletteratus* the gonads were very large and it is possible that their expanded condition was responsible for the displacement of the right lobe. However in comparable specimens of *yaito* and *lineatus* the right lobe was lateral in position.

Caecal Mass

This is large and prominent. It is variable in length and its extent, measured from the tip of the heart, ranged from 0.62 to 0.77 of the body cavity length. The latter was an extreme, while the former value approximates the average. The caecal mass tapers posteriorly to a point which generally lies on or near the median line. The mosaic appearance of its surface has been described above.

Liver

Of the three lobes, left and center are of approximately equal length, while the right is extremely long. The extent of the left and center lobes was, *in situ*, on an average 0.25 of the body cavity length, while that of the right ranged from 0.7 to 0.96. All lobes are shallow and flat. The center and left lobes are extensively lobulated and are intimately adherent to the caecal mass. The right lobe is attenuated and projects freely, being attached loosely to the membrane of the straight intestine. The left and center lobes, *in situ*, meet or overlap ventral to the caecal mass, and frequently are indistinguishable. The hepatic veins are plainly discernible on the ventral surface of all lobes. The excised liver (Figure 68) of *E. yaito* cannot be distinguished from that of other members of the genus, but is generically distinct.

FIGURE 68. *E. yaito*: Ventral view of excised liver

Stomach

This is a sac-like structure, in no obvious way different from that of other members of the Katsuwonidae. The pylorus arises ventrally on the left side. The stomach is long and in these specimens ranged from 0.86 to 0.92 of the body cavity length.

Intestine

As in all members of this family the small intestine is straight, without folds or convolutions. From its origin in the pyloric region the duodenum runs obliquely forward to the right side. In this extent it receives all the caecal ducts, which, however, were not investigated or counted. Reaching the anterior end of the body cavity on the right side the duodenum loops posteriorly, and as the small intestine it runs directly to the vent on the right side of the fish. A faint constriction marks the division between the intestine and the rectum.

Spleen

The spleen is concealed in ventral view as it appears to envelope partly the right anterior dorsolateral wall of the stomach. It is of the typical dark red color, and is highly variable in shape. In general it is relatively flat and wedge-shaped, with the apex posteriorly and the anterior end frequently expanded into a "Y". Suspended in the membrane, it is not intimately adherent to any other organ but projects freely into the body cavity.

Gall Bladder

This is located on the dorsal face at about the mid-length of the right lobe of the liver, lying between this and the stomach. It is loosely attached by the enveloping membrane to the right lobe, becoming more closely associated with the latter anteriorly where the bladder tapers into a bile duct. The bladder is generally a dark green, although it was occasionally a nondescript brown. It is roughly spindle-shaped, tapering at each end. As in other species of this genus, there is a deep cleft in the dorsal (or lateral) margin of the right lobe of the liver, into which the anterior end of the gall bladder customarily fits. However, in the majority of specimens of *E. yaito* the gall bladder was not contained within, or enveloped by the lobes of this cleft.

Air Bladder

There is no air bladder in this species.

Excretory System

Kidney

The kidney is a long, narrow wedge of tissue extending from an apex near the vent to the pectoral region where it abruptly expands into the lateral body wall. Anterior to this, the kidney was not investigated. The margins of the kidney are quite regular, with only slight and inconspicuous crenulations. The posterior termination of the kidney is occasionally obscure, as it may continue as a mere ribbon of tissue in the median line. This may, in extreme cases, extend to the end of the body cavity, but on the average the kidney terminates from two to five centimeters from the anterior margin of the vent. In terms of the vertebral column, the kidney extends to the vertical through the 22d or 23d vertebra.

Ureter

From the urinary bladder the ureter runs anteriorly in the median line. In this extent it is a relatively large vessel. The length of this undivided trunk is comparatively short, and the ureter divides shortly after entering the kidney substance. In the average specimen the division occurs beneath the 20th vertebra. From the division the two branches diverge slightly and then run anteriorly roughly parallel, separated by the width of the postcardinal vein. As the postcardinal swings to the right, the right ureter follows its course, while the left ureter follows a comparable path to the left. In the pectoral region the ureters curve abruptly, and as fine terminal vessels they run laterally and ventralward in this region of the kidney. Beyond this they were not followed.

The ureters of *E. yaito* are relatively large, straight vessels, comparable with those of *E. lineatus*. Like *lineatus*, the ureters of *yaito* have relatively few collecting tubules entering from the kidneys, and these are small and inconspicuous. In these respects *yaito* differs from the typical specimen of *alletteratus* in which the path of the branched ureters is erratic, the vessels are small, and innumerable collecting tubules join the ureter throughout its length. As these differences are relative and variable they must be used as a corroboratory rather than a positive character.

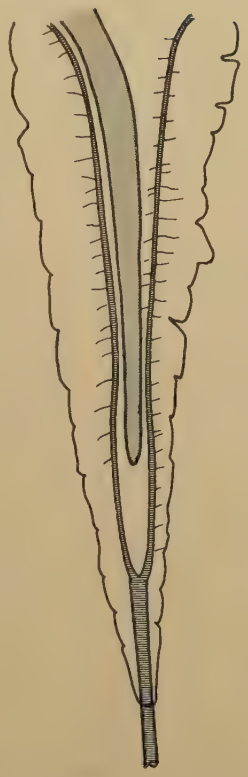

FIGURE 69. *E. yaito*: The posterior kidney mass and the course of the ureter. The postcardinal vein is shown separating the two branches of the ureter.

In at least two specimens the left branch of the ureter was larger and more superficial than the right. Anterior to the point where the two branches converged the left ureter ran on the surface of the kidney, directly beneath the connective tissue lining of the body cavity, while the right branch entered the substance of the kidney. The result was that the plane of the division was not horizontal, but oblique. In both these cases the left ureter was larger throughout its length.

Urinary Bladder

This was in no way different from that of *E. lineatus* and *E. alletteratus*. It is a greatly elongated oval sac, rounded at the anterior end and tapering to a posterior duct. It measured from 16 to 27 mm. in over-all length in these specimens. It lies against and attached to the dorsal wall of the body cavity between the gonads. In maturing females the bladder is concealed by the gonads which are fused posteriorly. The ureter joins the bladder usually at its anterior tip, but in occasional specimens several millimeters from the tip. It continues in the dorsal wall of the bladder for a distance of three to four millimeters before

opening into it. In this respect it resembles all the tunas and skipjacks investigated.

The excretory system of *E. yaito,* while differing in detail from other members of the genus, is not sufficiently or regularly different to serve as a diagnostic character. In general the fusion of the two branches of the ureter occurs more posteriorly in this species than in the other two.

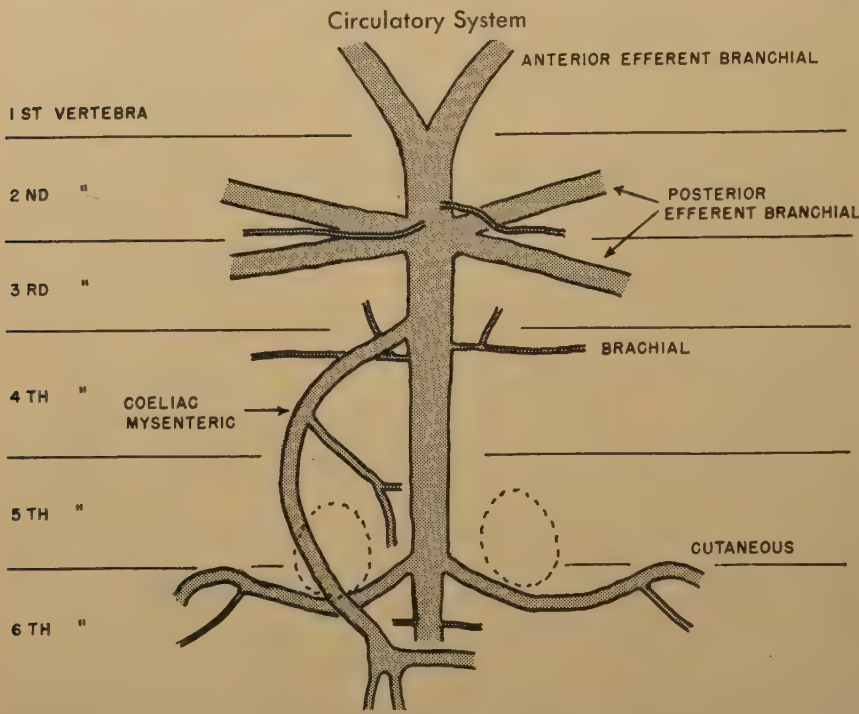

FIGURE 70. *E. yaito:* Anterior arterial system. The sketch is not quite typical. The cutaneous arteries, though occasionally curved at their origin as in this figure, arise perpendicular to the aorta in most specimens. The location of the pharyngeal muscles is shown in dotted outline.

Anterior Arterial System

The anterior efferent branchials fuse to form the aorta beneath the junction of the first and second vertebrae, or occasionally beneath the second vertebra. The posterior efferent branchials on each side fuse to form a negligible common trunk which joins the aorta beneath the junction of the second and third vertebrae. The coeliac mesenteric artery arises laterally on the right side beneath the junction of the third and fourth vertebrae. The brachials arise immediately posterior to this, beneath the anterior end of the fourth vertebra. The left brachial arises laterally, while the right brachial, because it originates almost simultaneously with the coeliac mesenteric artery, arises from the dorsolateral face of the aorta. The customary ligament is present immediately posterior to the brachials. In half the specimens the cutaneous arteries arose directly opposite each other. In the remaining specimens they were staggered in origin with the left cutaneous anterior to the right in the majority of such cases. Normally the cutaneous arteries arise beneath the sixth vertebra, with a variation from the junction of the fifth and sixth, to the junction of the sixth and seventh

vertebrae. The pharyngeal muscles attach to the sixth vertebra, extending on to the seventh.

This system is relatively simple in *E. yaito*, as in the other species of the genus. The expanse of aorta between the brachials and the cutaneous is devoid of appreciable segmentals. There is an indication that the cutaneous arteries are slightly more posterior in origin in *E. yaito* than in the two other species of this genus, but if any such difference exists it is slight, and of no diagnostic value. In all other respects the system is identical in these three species.

Visceral Arterial

The coeliac mesenteric artery always arises on the right side of the aorta, normally beneath the junction of the third and fourth vertebrae or as often beneath the anterior portion of the fourth vertebra. The designation of its subsequent branches is interpretative, and is governed by analogy of function in the tunas. Actually there is in *Euthynnus* nothing comparable with the clearly distinct and separate branches of the Thunnidae, so that apparent differences between this text and subsequent observations must be attributed to this interpretation. In reality the coeliac mesenteric artery does not divide into the three typical branches of the tunas. Instead it gives off one small and negligible branch and then pours its entire supply into three intricate reticulations within the respective lobes of the liver. From these plexuses come the separate terminal vessels to the viscera, rather than from major divisions of the arterial trunks. This fact was obscured in early dissections both by prejudice of previous dissections and by the complexities in the origins of the visceral vessels which were extremely difficult to determine. Because the descriptions of *E. lineatus* and *E. alletteratus* were written earlier with the pattern of the tunas in mind, this description will also follow the same interpretation.

From its lateral origin in the aorta the coeliac mesenteric artery turns posteriorly and gives off (within half an inch of its origin) a small to minute No. I branch. This vessel runs posteriorly on the wall of the esophagus and soon divides. Branch I-a (Fig. 71) continues posteriorly and approaching the head of the spleen, it loses its identity in an anastomosing network of small vessels emerging from the right lobe of the liver. (Discussion of this will be found under the No. II branch.) However, I-a, augmented by a supply from this network, continues along the right dorsolateral wall of the stomach to its tip. The second branch, labeled I-b, turns transversely, crosses in the dorsal wall of the esophagus to the left side, and on the anterior left dorsolateral wall of the stomach it turns posteriorly and, joined by arterial strands from the No. III branch, it runs in this face of the stomach to its posterior tip. At the point where these branches of the No. I and No. III meet, a small anastomosing network is formed and from this network a small arterial strand runs posteriorly in the membrane to the left gonad. Because this is the normal function and location of the No. I branch in the tunas, this vessel in *Euthynnus* has been so interpreted and labeled. In *E. yaito* the No. I branch is small, insignificant and easily overlooked.

The trunk of the coeliac mesenteric artery continues posteriorly and ventrally to the head of the liver without dividing or giving rise to any major vessel. In this extent it does give rise to several minute vessels

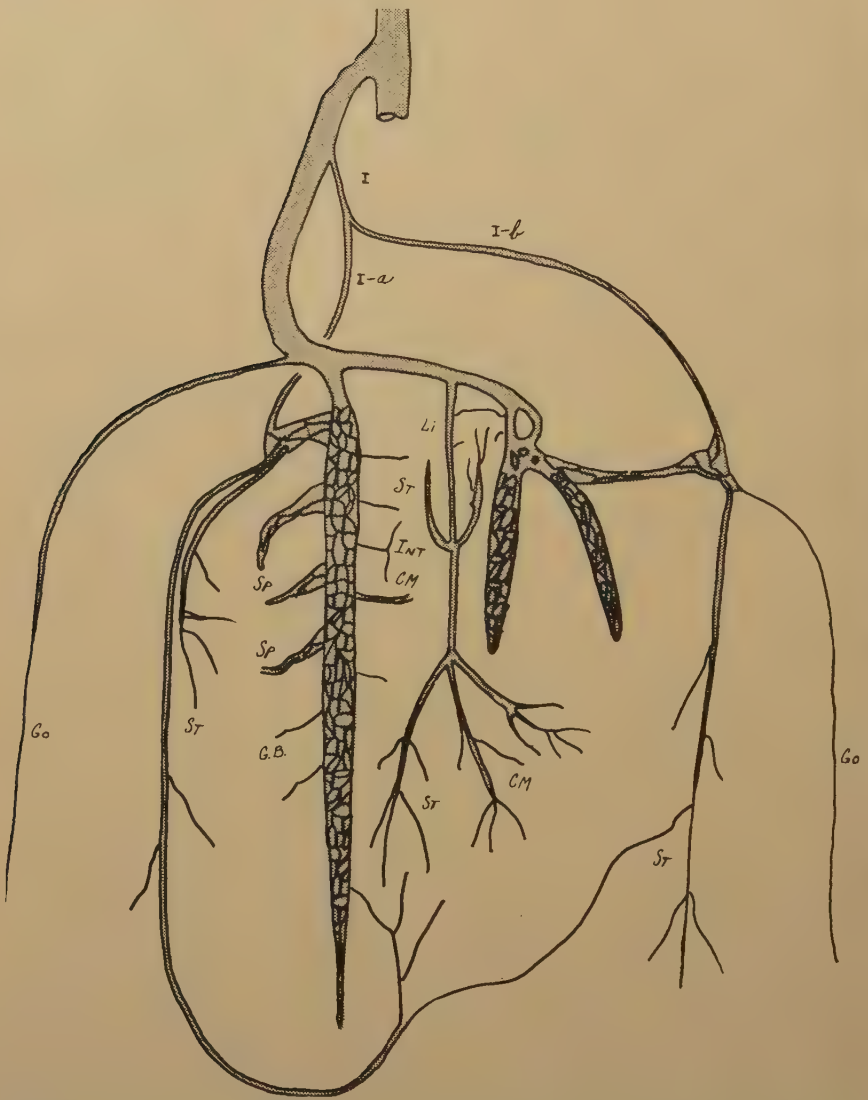

FIGURE 71. *E. yaito:* Diagrammatic sketch of the coeliac mesenteric artery. CM = caecal mass. GB = gall bladder. Go = gonad. Int = intestine. Li = liver. Sp = spleen. St = stomach.

into the kidney, esophagus and adjacent tissues which were not individually followed. One such vessel however is of interest. Just before reaching the head of the liver (in the vicinity of the right hepatic portal vein) the trunk of the coeliac mesenteric artery gives rise to a small to minute vessel which runs directly to the right gonad. Frequently this vessel is joined by one or more similar small arterial strands coming from the head of the liver, or subsequently from the trunk itself. As often the vessel to the right gonad arises in the network at the head of the spleen.

Reaching the head of the liver the coeliac mesenteric artery runs directly to the right hepatic portal vein, as that discharges into the

Cuvierian duct. At this point the coeliac mesenteric divides into its two major constituents, the No. II and No. III branch. The division is neither precise nor stereotyped, but is intricate and variable. While the No. III branch continues as a large discrete vessel towards the left side in the substance of the head of the liver, the No. II branch literally disintegrates progressively into innumerable anastomosing branches which immediately surround and enmesh the walls of the large hepatic vein running the length of the right lobe. It is from this network, in multiple origins, rather than from a distinct No. II branch, that the separate visceral vessels arise.

From the head of the right lobe of the liver, a number of small arterial strands emerge from its dorsal surface and form a reticulation (to which branch I-a contributes) from which arise by subsequent fusion, one, two or three parallel, adherent and separate vessels of moderate size, which, together, continue posteriorly in the right dorsolateral wall of the stomach. This vessel (or a component of the two or three constituent parts) continues to the posterior tip of the stomach, nourishing the entire adjacent stomach wall in its course. Reaching the tip of the stomach this vessel, instead of ending in terminal branches, leaves the stomach wall and recurves anteriorly in the mesentery and forms the peculiar and inexplicable arterial loop characterizing this genus. In the one specimen in which this was completely injected this loop branched as it approached the intestine. The first branch continued in the mesentery to the left side where it rejoined the stomach on that side, and finally merged with a terminal portion of the No. I branch running in the left dorsolateral wall of the stomach. The second branch, which was the larger of the two, ran anteriorly in the mesentery of the intestine, and finally re-entered the substance of the right lobe of the liver near its posterior tip. Before doing so, however, it gave rise to two moderate branches which terminated on or in the ventral wall of the stomach.

This arterial loop constitutes a generic character of *Euthynnus*. It is most confusing and poses the problem of the direction of flow of blood at the confluence of the vessels. The existence of this loop has been repeatedly observed and demonstrated.

From the head of the right lobe of the liver a second series of small vessels arise, fuse completely or partially and as one or more distinct small vessels, run into the anterior portion of the spleen. Posterior to this at least two other separate vessels, each with a multiple origin within the right lobe, run respectively to the central and posterior portions of the spleen. In addition, a number of small vessels run transversely into the dorsal face of the caecal mass. Many of these vessels are paired and although the visceral venous system was not injected the appearance of such pairs suggested that they enclosed a corresponding vein, as so frequently occurs both in the Katsuwonidae and Thunnidae. Again, many of these small vessels join arteries in the caecal mass which originate in the No. III branch.

In addition to the foregoing vessels the No. II branch (via the network surrounding the right hepatic vein) supplies numerous small short vessels to the intestine and also to the gall bladder. Thus the No. II branch nourishes mainly the right lobe of the liver, the right side of the stomach, and the spleen, and secondarily the intestine, gall bladder and the caecal mass.

The No. III branch: After giving rise to the No. II branch, the trunk of the coeliac mesenteric artery, as the No. III branch, continues transversely to the left hepatic portal vein. In this course it sends numerous minute branches and sometimes one appreciably larger branch into the substance of the liver. Reaching the left hepatic portal vein at its confluence with the heart, the No. III branch usually bifurcates as a collar around this vein, which is the fused trunk of the hepatic veins in the center and left lobes. It immediately and progressively breaks up into two reticulations which surround respectively the center and left hepatic vein.

The origin of the remaining visceral vessels is in part obscure. The caecal mass, the pylorus, duodenum and the ventral wall of the stomach are nourished by a major vessel or a cord of smaller adherent ones which arise, either from the fusion of innumerable arterial strands emerging from the dorsal face of the head of the liver, or partly from the vessel given off the No. III branch at the hepatic portal vein. The dissection of this portion of the system is extremely difficult because of the intimate adherence of the several organs, and no two specimens were quite alike. Whatever its origin, the subsequent pattern of this system was clear. The trunk, or its counterpart, runs from the liver into the caecal mass to the pylorus. Here it sends a moderate vessel to the pylorus and another in the mesentery to the stomach. The latter vessel runs anteriorly in the mid-ventral wall of the stomach. Just posterior to this the trunk of the No. III breaks up into three large terminal branches. Two of these fan out over the dorsal surface of the posterior caecal mass while the third crosses in the mesentery to the ventral wall of the stomach where it runs posteriorly in its mid-ventral line, sending numerous branches over the adjacent stomach wall.

Emerging from the left lobe of the liver, at its head, are a few arterial strands which cross in the mesentery to the left side of the anterior stomach wall. These vessels, either separately or fused, participate in the formation of a small network to which the No. I branch (I-b) contributes, and from this network a vessel emerges that runs posteriorly along the left dorsolateral wall of the stomach. It is also from this network that the vessel to the left gonad arises. The No. III branch thus nourishes primarily the center and left lobes of the liver, the caecal mass, the ventral wall of the stomach, and the proximal region of the intestinal tract.

The foregoing is the basic major pattern of visceral arterial circulation in *E. yaito*. There is excessive variation in detail, and no significance need necessarily attach to it. This description duplicates that of *E. lineatus* and *E. alletteratus* and no specific differences were detected. The subordination of the No. I branch, the late division of the coeliac mesenteric trunk, the complex reticulations surrounding the hepatic veins, and finally the complete loop in the No. II branch are characters peculiar to the genus *Euthynnus*.

Cutaneous System

The cutaneous arteries normally arise beneath the sixth vertebra and run laterally, usually perpendicular to the aorta, through the kidney tissue. In this extent they give rise to a number of minute vessels which nourish the kidney and contribute to the arterial reticulations in the walls of the adjacent large veins. The artery on each

side continues to the ribs, and passes laterally, with the vein, typically between the third and fourth ribs. It is peculiar that on both sides of the eight specimens investigated, the vein and artery passed between the third and fourth ribs in nine cases and between the first and second ribs in the remaining seven. In no instance did it go between the second and third ribs. Moreover, in seven of the eight specimens, passage was between the third and fourth ribs on at least one side, and between these ribs on both sides in two cases. In five cases passage was between different ribs on the two sides. In only one case did these vessels pass between the first and second ribs on both sides.

Just mesial to the ribs the cutaneous artery on each side gives rise, typically, to two small vessels, one on the anterior and the other on the posterior face of the artery. The anterior one runs into the kidney and appears to terminate in the walls of the Cuvierian duct. The posterior one runs ventrally in the lateral kidney mass and in some but not all cases becomes the ventral branch of the cutaneous artery. This will be discussed separately.

Continuing laterally, the cutaneous artery—with the accompanying vein—passes between the fourth and fifth intermuscular bones. This again is variable. The extremes encountered were between the second and third, and the sixth and seventh intermuscular bones. In nine cases out of the 16, however, passage was between the fourth and fifth intermuscular bones. Frequently the two sides of the same fish differed.

Throughout this extent the cutaneous vein accompanies the artery. From the region of the Cuvierian duct (into which the vein discharges indirectly, via the complex venous system of the anterior kidney mass) to the surface, the vein runs with, anterior to and approximately on the same horizontal plane as the cutaneous artery. The latter sends a fairly continuous though irregular series of capillaries into the walls of the cutaneous vein. Just dorsal and posterior to the pectoral insertion the cutaneous vessels reach the surface musculature and in this vicinity the vein crosses the external face of the artery and from thence posteriorly the vein lies ventral to the artery and approximately on the same surface plane. Vein and artery continue posteriorly, as the dorsal cutaneous vessels, in a relatively straight line, and disappear in the caudal region in the surface musculature as small branching terminal vessels.

Throughout their extent in the surface musculature both vein and artery receive or give rise to segmentals and to capillary sheets. The segmentals run both dorsally and ventrally from both vein and artery. They are somewhat erratic in occurrence, and the dissections and figures suggest that they are more fully developed in alternate segments, with smaller ones between. The dorsal venous segmentals may cross either face of the artery, but in most cases they cross its external face. The dorsal segmentals, both venous and arterial, are more regular and parallel in course: the ventrals are more dendritic.

The arterioles giving rise to the capillary sheet arise in a single irregular row from the proximal, axial face of the artery. The arterioles are more widely spaced than the venules. Whereas the latter resolve immediately into capillary bundles, the arterioles branch anteriorly and posteriorly and the capillary sheets arise by subsequent branching. Although fairly continuous this row of arterioles is frequently interrupted by short spaces in which no arterioles arise.

A corresponding row of venules discharges into the axial face of the vein. This row is somewhat irregular in origin, and could be interpreted as a double, alternating row. As with the arterioles there are occasional interruptions in the continuity of this row, with interspaces in the resulting capillary venous sheet. The venous and arterial capillary sheets are inextricably merged, running axially, but in several longitudinal planes into the blood meat of the lateral line.

The ventral cutaneous vessels are entirely different, and incipient or rudimentary. In fact they are, in approximately half the specimens, not even connected with the dorsal branch which has been described. The ventral cutaneous veins were not investigated. The artery has an unstable or variable origin. It may arise as a minor branch from the trunk of the cutaneous artery, or it may arise in the brachial artery. Frequently the origin is associated with both these vessels.

From the above description it will be noted that the cutaneous artery on each side gives rise to a pair of small vessels, one anteriorly, the other posteriorly, just before passing laterally between the ribs. In some specimens the posterior vessel continues ventrally through the kidney and emerges in the surface musculature at the ventral base of the pectoral insertion, as the ventral branch of the cutaneous artery. In other cases the brachial artery continues posteriorly beyond the pectoral insertion and emerges in the surface musculature as the ventral cutaneous artery. In still other cases the ventral cutaneous artery arises by the fusion of arterial strands originating both in the brachial and in the small branch described above arising in the cutaneous artery in the vicinity of the ribs. Because of its association with the ventral cutaneous, the course of the brachial was followed in all dissections.

The brachial arises in the dorsal aorta, invariably in the immediate vicinity of the origin of the coeliac mesenteric artery. Each brachial runs laterally, perpendicular to the aorta. At a distance of $\frac{1}{4}$ to $\frac{1}{2}$ inch from its origin each brachial divides into two approximately equal vessels. One branch turns anteriorly at its origin, perpendicular to the trunk and runs anteriorly and dorsally to the skull. This branch was not further investigated and will not be considered. The second branch, referred to henceforth as the brachial, continues laterally into the anterior kidney tissue and curves posteriorly and ventrally. It gives off numerous minute branches into the kidney and many of these little vessels run characteristically in the walls of the large anterior veins. It continues ventrally towards the clavicle where it normally divides into a major and one or more secondary branches. The major branch normally turns laterally and goes to the pectoral girdle. Its fate was not determined, but it appears to nourish the base of the pectoral fin or possibly the tissues enveloping the postclavicle or clavicle. A consistent, diminishing secondary branch continues posteriorly to disappear in the musculature at the base of the pectoral fin. In many specimens this particular secondary branch is enlarged and as the largest component of the brachial it continues posteriorly into the surface musculature in the pectoral region to become the ventral cutaneous artery. In the two sides of the same fish, the ventral cutaneous may have a different origin.

Whatever may be their origin the ventral cutaneous vessels are short and dentritic. They are strictly superficial and in much of their course

they are closely adherent to the skin. They are in no sense comparable with the dorsal cutaneous vessels or with the cutaneous system of the Thunnidae. The pattern of this system in *Euthynnus* is esesntially that of the Katsuwonidae. The pattern is exactly comparable with that described for *E. lineatus* and *E. alletteratus*, and no diagnostic differences were observed in it. The peculiarities of the system are generic. *Euthynnus* differs from all other genera in that the dorsal cutaneous artery lies dorsal to the vein in the surface musculature.

Postcardinal Vein

As in *E. lineatus* and *E. alletteratus*, which do not differ in this respect, the postcardinal vein is an immense vessel emerging from the haemal canal through the first completed haemal arch. From here it runs anteriorly in the mid-dorsal wall of the body cavity within the substance of the kidney, separating the two branches of the ureter. Approaching the heart it progressively enlarges and in the pectoral region it swings to the right and joins the right Cuvierian duct. It appears to flow directly into this duct without the intervention of perforated membranes, for such were not observed in the dissections. Although the connection of the cutaneous veins with the postcardinal was not apparent, nor was it closely investigated, there is undoubtedly such a connection, because latex injected into the cutaneous vein flowed freely and regularly into the postcardinal.

The dorsal aorta lies in the dorsal wall of the postcardinal vein. It gives rise to a continuous, closely spaced lateral series of arterioles on each side which run and anastomose in the lateral walls of the postcardinal and flow thence into the substance of the kidney.

At the point where the postcardinal leaves the haemal canal, it is joined by a moderate renal vein from that portion of the kidney lying posteriorly. This renal vein runs in the median line and disappears posteriorly in the vicinity of the juncture of the ureters. This vein is not readily apparent except in injected specimens.

A comparison of the foregoing description with Kishinouye's description of *E. yaito* leaves no doubt as to the identity of the present material. There is essential agreement in all detail. The Hawaiian stock, as represented by this sample, must therefore be referred to *E. yaito*.

In September, 1952, the writer received a specimen of *Euthynnus* which resembled in markings an extreme variant of *E. lineatus*. This specimen was caught in a bait net inshore from the breakwater of the Los Angeles Harbor on the night of September 23, 1952. Mr. M. L. Smith recognized it as an exotic specimen and the following morning delivered it to this laboratory for identification. His interest is gratefully acknowledged.

The writer made a complete dissection and wrote a separate description of it. The skeleton was prepared, and this, with the description, was later compared with the specimens of *E. yaito* subsequently received from the Hawaiian Islands. The description was a replication of that prepared for *E. yaito*, and the structure of the vertebral column proved conclusively that this specimen was none other than *E. yaito*. Fitch (1953) has recorded this occurrence, which thus extends the range of this species to this coast, however rare this occurrence may be.

FIGURE 72. Little tunny of the Atlantic: *Euthynnus alletteratus*. Specimen No. 5, taken June, 1952, in 20 fathoms, northwest of Dry Tortugas, Florida. (*Photo by Herb Phillips, San Pedro.*)

LITTLE TUNNY (*Euthynnus alletteratus*)

This description is based on eight specimens. One of these was derived from a small commercial shipment received by a canner in the Los Angeles Harbor region in November, 1942, from the Fulton Fish Market, New York City. Beyond the fact that the fish were taken along the Atlantic Seaboard, no precise origin is available. This specimen was subjected to a complete dissection and the notes were compiled in manuscript form at the time and filed with the original sketches. The sketches and the original description were checked against the results of the remaining seven dissections which were made in 1952, and the observations combined in the present paper.

The seven specimens were part of a shipment sent to the author by the U. S. Fish and Wildlife Service expressly for this purpose. Six of these were a part of an eight-ton catch made in 20 fathoms northwest of Dry Tortugas, Florida, in early June, 1952. The seventh specimen was taken off Pascagoula, Mississippi, in late June, 1952. For these fish we are indebted to Mr. L. R. Skelton of the U. S. Food and Drug Administration, and to Mr. Stewart Springer of the U. S. Fish and Wildlife Service.

EXTERNAL CHARACTERS

This species can be superficially separated from others in the genus by the absence of vomerine teeth, and by the pattern of dorsal markings. The latter, illustrated in Figures 72 and 73, consists of broken, longitudinal black or dark bars running irregularly from the corselet towards the caudal region. These markings are more continuous and regular posteriorly. Anteriorly the bars are replaced by short irregularly curved lines, blotches or by spots. The two illustrations are typical of the specimens handled. The markings are superimposed upon a background of blue, shading dorsally into the deep blue and black of the mid-dorsal line. Below the lateral line the blue fades into silver and the entire belly is silvery or dusky, with an irregular number of black or dark spots between ventral and pectoral fins, and slightly posterior to the pectorals.

FIGURE 73. Little tunny: This illustrates the extent and shape of the corselet, and variation in the pattern of markings

The color of the fins was not consistent. In some specimens there was a small dark spot below the posteroventral margin of the eye, but this was inconspicuous or absent in others.

The ventral projection of the corselet is variable but generally short. It extends posterior to the tip of the pectoral a distance not exceeding one-fourth the length of the pectoral fin in most specimens, but is occasionally longer. The lateral line curves gently upward above the pectoral fin, and is of no diagnostic value. The maxillary extends posteriorly to the vertical through the middle of the eye. In this respect it differs from *E. yaito* in which the extension of the maxillary is greater. The posterior margin of the operculum is relatively straight; that of the preoperculum smoothly rounded. The teeth are moderate in size and individually distinct. There are approximately 25 to 35 teeth on each side of the lower jaw, and they are similar to those of the other described species of this genus. The palatine teeth are sharp, strong and quite conspicuous. There are no vomerine teeth. However, a median longitudinal ridge of bone in this position can be felt in some specimens. The tongue has a longitudinal dorsal ridge on each lateral margin. These are variable in development but invariably present.

The interpelvic processes are typically divided (Figure 66), but the division was incomplete in one case, with only the tips of the paired processes distinct.

The dorsal fins are normally contiguous. In one specimen, however, the dorsals were divided as in *Auxis*, and the length of the first dorsal base was only half the distance separating the insertion of the two dorsal fins. In this specimen there were only 10 dorsal rays in place of the customary 15. The first dorsal is high, but it is proportionately lower than in *E. yaito*. The distal margin of the first dorsal is strongly concave. The anal fin is inserted on or posterior to the vertical through the end of the second dorsal base. In this respect it is more anterior than in *E. yaito* or *E. lineatus*. There are eight dorsal and seven anal finlets.

Gill rakers are present on the first arch only. There is at the angle of the arch one raker with both a dorsally and a ventrally projecting basal process. This appears to characterize the genus. The gill raker count was 10(10-11) + 1 + 26(26-28) = 37(37-40) (Table 14) which is sufficiently different to separate it from *E. yaito*.

There are two or three short rakers at the angle of the second and subsequent arches, and a few short or rudimentary rakers on the upper limb of the third and fourth arches. This was casually noted in two specimens. Apparently the condition is comparable with that described for *E. lineatus*. There are posterior rakers or gill teeth on all arches. Those of the first arch are longest and most developed, while those on succeeding arches become progressively smaller. The count of such posterior rakers on the first arch was 9 + 23 = 32.

TABLE 14

Atlantic Little Tunny: Meristic Counts Made Upon Eight Specimens

	Fish number							
	42	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
1st dorsal rays	15	15	--	10	15	15	15	14
2d dorsal rays	13	12	--	13	12	12	13?	13
Dorsal finlets	8	8	--	8	8	8	8	8
Anal rays	14	15?	--	11	13	12	14	13
Anal finlets	7	7	--	7	7	7	7	7
Gill rakers:								
Upper limb	11	10	10	11	10	10	10	10
Angle	--	1	1	1	1	1	1	1
Lower limb	26	26	27	28	26	26	26	28
Total count	37	37	38	40	37	37	37	39

TABLE 15

Atlantic Little Tunny: The Measurements Made Upon Seven Specimens and the Range in the Resulting Ratios, of Which Body Length Is the Numerator in Each Case Except Those Indicated by an Asterisk. In the Latter the Head Length Becomes the Numerator.

	Fish number							
	No. 42	No. 1	No. 3	No. 4	No. 5	No. 6	No. 7	Ratios
Body length	637	677	763	726	690	503	704	
Head length	164	181	196	192	189	131	185	3.65– 3.89
1st dorsal insertion	189	197	215	209	202	142	199	3.37– 3.55
2d dorsal insertion	362	394	433	410	399	284	ca 385	1.72– 1.77
Anal insertion	406	431	484	450	440	317	ca 428	1.57– 1.61
Ventral insertion	184	202	224	213	211	152	208	3.27 3.46
Greatest body depth	153	173	185	177	176	122	175	3.91– 4.16
Greatest body width	105	ca 118	ca 124	ca 118	ca 118	--	115	6.07– 6.12
Dorsal-ventral distance	147	165	175	169	169	116	166	4.08– 4.36
Dorsal-anal distance	260	285	320	294	287	208	282	2.37– 2.50
Ventral insertion to vent	--	233	266	236	230	163	226	2.87– 3.12
Length of 1st dorsal base	185	205	224	208	204	146	197	3.30– 3.57
Length of 2d dorsal base	45	43	50	48	40	32	49	14.16–17.25
Length of anal base	43	45	49	49	43	32	51	13.80–16.05
Pectoral length	98	115	Broken	118	116	ca 84	ca 111	5.89– 6.50
Height of 1st dorsal	84	97	102	102	100	65	Broken	6.90– 7.74
Height of 2d dorsal	47	52	64	65	64	38	60	10.78–13.55
Height of anal	50	--	--	65	64	Broken	63	10.78–12.74
Diameter of iris	21	22	--	23	23	ca 19	23	*7.81– 8.35
Maxillary length	62	68	77	70	71	ca 50	70	*2.54– 2.74
Snout to posterior margin of eye	--	--	--	79	77	--	--	*2.43– 2.45

PROPORTIONAL MEASUREMENTS

While these are tabulated in Table 15 a discussion of them will be deferred until the identity of the several species is considered.

INTERNAL ANATOMY

Viscera

The ventral view of the viscera, *in situ*, in the specimens examined was dominated by the long right lobe of the liver, the caecal mass and the large gonads. Little else was seen. In some specimens a part of the gall bladder was visible. Occasionally, a small portion of the spleen showed anteriorly against the right body wall, as in Figure 74. This results from the distention of the stomach which crowds the contiguous spleen against the body wall. *E. alletteratus* is the only species in the genus in which the spleen ever shows in this view. In one respect this view was specific, differing from all species in the genus. In every specimen the right lobe of the liver was median in position instead of lateral as in *yaito* and *lineatus*. While in the two latter species the right lobe was enclosed between the remaining viscera and the lateral body wall, so that it was partly concealed in this view, in *alletteratus* the right lobe lies near the center line, ventral to the other visceral organs, so that its entire flattened expanse was visible. It is possible that the large gonads may have been responsible for a displacement of the viscera. However, in no comparable instance was this view duplicated in *yaito* or *lineatus*. Hence this view provisionally constitutes a corroboratory specific character.

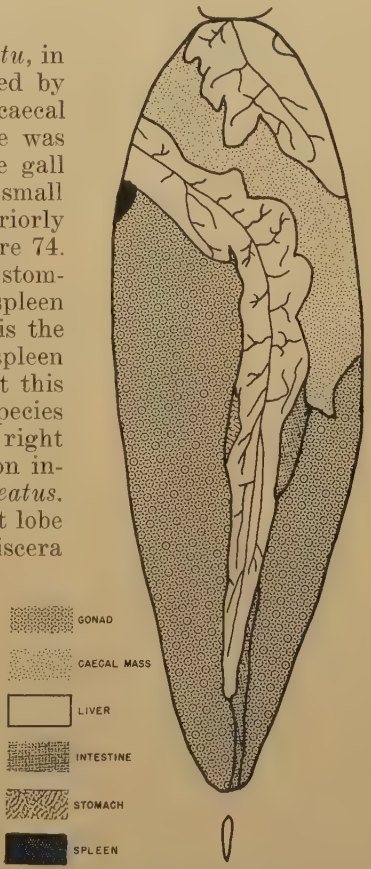

FIGURE 74. Little tunny: Ventral view of the viscera, *in situ*. The median position of the attentuated right lobe of the liver was typical of these specimens. Exceptionally, a small portion of the spleen is seen laterally, as in this view.

Caecal Mass

The caecal mass is moderate in extent and lies predominantly on the left side of the body. The posterior tip extended slightly beyond the mid-length of the body cavity. This organ is well defined in outline, firm in texture (which incidentally is not unlike that of the liver) and somewhat granular in appearance. It lacks the finely striated appearance characterizing the tunas proper. The caecal mass is intimately adherent

FIGURE 75. Little tunny: Ventral view of excised liver. The hepatic veins, characteristic of this genus, are not shown in this figure.

to the center and left lobes of the liver and to the anterior portion of the right lobe. It connects with the duodenal region of the intestine through about seven compound caecal ducts, six of which empty through the posterior wall and one through the anterior wall of the duodenum. Apart from the granular appearance there is nothing distinctive about this organ.

Liver

The liver is composed of three relatively thin lobes, of which the right is by far the longest. *In situ,* the long right lobe is distinct and separate. The short center and left lobes frequently overlap and cannot be clearly differentiated. They are approximately equal in extent, and both are intimately adherent to the caecal mass. Hepatic blood vessels are present on the ventral surface of all lobes, as illustrated in Figure 74. There are no vascular plexuses dorsal to the liver. The right lobe is specifically distinct in location. In this species it is relatively median in position, ventral to the remaining viscera and the entire width of the attenuated portion shows *in situ.* To this extent it constitutes a strongly corroboratory character. Of the three species of *Euthynnus* investigated the excised liver (Figure 75) is similar in all.

Stomach

The stomach and intestine are sketched in Figure 76. The stomach is a long blind sac, as in all the tunas, extending almost the full length of the body cavity. No detailed observations were recorded.

Intestine

This originates at the anterior end and on the left side of the stomach. It loops anteriorly across the ventral wall of the stomach and

reaching the proximal end of the body cavity on the right side, it runs directly back without fold or undulation, to the vent. In this respect it is similar to all species of Katsuwonidae. The regions of the intestine are indicated by either change in diameter or change in color. The system of caecal ducts while similar to other described species, is conspicuous in this genus. The largest such duct, opening into the duodenum at its proximal end, gives rise to a regular vascular system permeating the entire posterior portion of the caecal mass. This system of ducts is conspicuous on the dorsal face of the caecal mass.

FIGURE 76. Little tunny: Alimentary canal, showing the straight course of the intestine and the anterior origin of the intestinal tract

Spleen

The spleen does not normally show in ventral view of the viscera, *in situ*. It lies dorsal to and thus covered by both the right lobe of the liver and the caecal mass. It is located at the extreme anterior end of the body cavity, on the right side, enclosed between the head of the liver and the lateral wall of the stomach. It is a moderately long compact organ, its length being 0.3 that of the body cavity. As the right lobe of the liver turns—or angles—transversely from the right to the left side of the fish, the tip of the spleen sometimes continues beyond its margin, and in such cases may be seen in ventral view.

Gall Bladder

This is a tubular structure between seven and eight centimeters long (in these specimens) located centrally on the dorsal face of the right lobe of the liver. In color it is a vivid green. The anterior end, which tapers into a bile duct adheres to the face of the liver, but the posterior extremity projects more or less free of this. In occasional specimens the anterior end of the distended gall bladder may protrude into ventral view beyond the lateral margin of the right lobe of the liver. Such specimens approach the appearance in *Auxis*.

Air Bladder

There is no air bladder in this species.

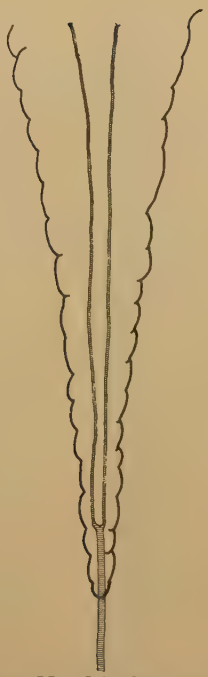

FIGURE 77. Little tunny: Outline of the posterior kidney mass and the course of the ureter.

Excretory System

Kidney

The posterior portion of the kidney extends as a narrow wedge of tissue in the mid-dorsal wall of the body cavity for a distance equal to about 0.8 of the total length of the body cavity. The tip of the kidney lies, on the average, beneath the 22d vertebra. The lateral margins of the kidney are slightly indented or crenulated (Figure 77). Anteriorly this wedge of kidney tissue expands laterally in the pectoral region, but the anterior portion was not particularly observed.

Ureter

The trunk of the ureter enters the urinary bladder at or very close to its anterior end. From the bladder the trunk runs anteriorly in the mid-dorsal line and enters the substance of the kidney. It runs as a single trunk a total distance equal to 0.3 the length of the body cavity (variation, 0.2 to 0.4) and then separates into two branches. The fusion of the two branches occurs most frequently beneath the 20th vertebra. The two branches run anteriorly parallel and close to the mid-dorsal line. At a distance of approximately two vertebrae anterior to the fusion, the ureters contact on either side the postcardinal vein as that emerges from the haemal canal to enter the substance of the kidney. The ureters run anteriorly in apparent contact with or close to the lateral walls of the postcardinal and continue anteriorly. The right branch of the ureter follows the postcardinal as that swings towards the right Cuvierian duct, while the left branch leaves the vein at this point and follows a comparable path to the left. In the majority of specimens the two branches of the ureter were small and their course was mildly erratic. They were difficult to follow because of their small size and occasional abrupt changes in course. In places they appeared to consist of bundles of collecting tubes. To this extent they were at first considered specifically distinct from the comparable structures in *yaito* and *lineatus*. However, in the last two specimens investigated the branched ureters were in both cases large, relatively straight and essentially comparable with *yaito* and *lineatus*. Hence the difference must be attributed to individual rather than specific variation. At best the difference is relative, and when present, corroboratory.

Urinary Bladder

This is inconspicuous, and in the majority of specimens it was difficult to observe and delimit because of the large developing gonads. It is located in the mid-dorsal line, attached throughout its length to the extreme posterior end of the dorsal wall of the body cavity. It appeared

to be thin-walled, and not conspicuously different from the texture of the membranes enveloping the gonads. The ureter enters the bladder at or close to its extreme anterior end, but as in the tunas generally the ureter appears to run within the bladder a distance of two to four millimeters before terminating in an internal orifice.

The excretory system of this species is similar to that of *E. yaito* and *E. lineatus*. In many specimens it appears to differ from the two latter species in the size and course of the ureters; but as the ureters in occasional specimens could not be distinguished from those of *yaito* and *lineatus*, the character is of little diagnostic value.

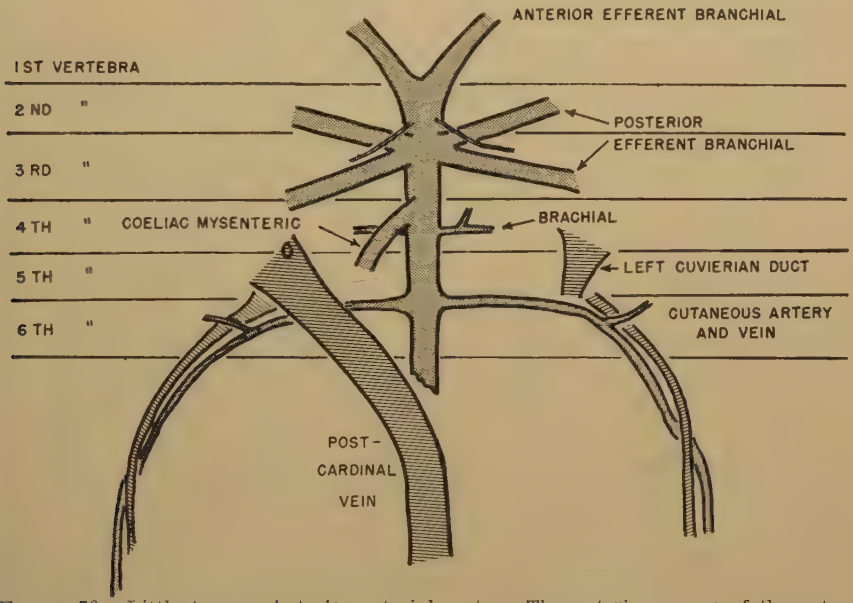

FIGURE 78. Little tunny: Anterior arterial system. The anterior course of the cutaneous veins is also shown, with a portion of the postcardinal vein and left Cuvierian duct.

Circulatory System

Anterior Arterial

This is not significantly or perceptibly different from that of other species of the genus. The arrangement is illustrated in Figure 78. The "Y" of the aorta is beneath the junction of the first and second vertebrae, or as often beneath the anterior half of the second vertebra. The posterior efferent branchials join to form a short common trunk which fuses with the aorta beneath the junction of the second and third vertebrae or as often beneath the anterior half of the third vertebra. The coeliac mesenteric artery originates in the aorta on the right side beneath the anterior portion of the fourth vertebra or occasionally beneath the junction of the third and fourth vertebrae. The brachial arteries originate with or immediately posterior to the coeliac mesenteric beneath the fourth vertebra. The characteristic ligament immediately posterior to this was seen in about half the specimens. The cutaneous arteries arose opposite each other in all specimens, either beneath

the junction of the fifth and sixth vertebrae or beneath the anterior portion of the sixth vertebra. The pharyngeal muscles attach to the sixth vertebra, extending to portions of the fifth and seventh. The first completed haemal arch was quite variable in location, occurring on the 16th vertebra in two specimens, on the 17th in one, on the 18th in four and on the 19th in one specimen.

Visceral Arterial

The number of satisfactory injections of this system was limited, and this description will encompass only the basic pattern of visceral circulation and such detail as appeared common to all specimens. Measurements cited in this section relate to specimens about 70 centimeters in body length.

The visceral circulation in this species is typical of the genus. The coeliac mesenteric artery arises in the aorta on the right side, typically beneath the anterior end of the fourth vertebra. As in the other species, it gives off a small, negligible No. I branch within a half inch or so of its origin. The trunk continues intact without further division until it reaches the right hepatic portal vein. Thus the generic pattern differs from the Thunnidae in which the coeliac mesenteric artery divides earlier into its three components.

The No. I branch separates, normally, into two small branchlets. One goes posteriorly to join the network on the right anterior wall of the stomach, from which emerge the trunks nourishing the right side of the stomach. The other crosses in the dorsal wall of the esophagus and on the left anterior dorsolateral wall of the stomach joins—directly or indirectly—a component from the No. III branch which nourishes the left side of the stomach. The No. I branch is generally a negligible branch, and can be easily overlooked. In one specimen the two minute parts of the small No. I branch arose separately, but adjacent, in the trunk.

Just beyond the origin of the No. I branch, a small vessel arises in the trunk and runs directly to the head of the right gonad. This small vessel is generally joined by contributing arterial strands arising in the network beneath the head of the right lobe of the liver.

The No. II branch originates in the bifurcation of the coeliac mesenteric trunk in the wall of the right hepatic portal vein. This is not a clean division into two parts, but rather a division into two major and three or four minor branches. One major component constitutes the No. II trunk. The other is the No. III branch. The minor components are inextricably confused. They branch and rejoin and eventually send their supply of blood directly back into the No. III trunk or indirectly to this branch via the network surrounding the left hepatic portal vein. They are considered here as portions of the No. III trunk.

The No. II branch breaks up at its origin into several moderate, parallel branches which run the length of the right lobe of the liver in the walls of the right hepatic vein. These trunks anastomose profusely throughout, and form the typical reticulation enmeshing this vessel. From this network the individual visceral vessels arise in multiple and obscure origins. The first such vessel results from the fusion of innumerable arterial strands which emerge from the head of the right lobe. These strands originally form a network in the mesentery, and

from this network two or three parallel adherent moderate vessels run to the stomach and continue posteriorly in its right dorsolateral wall. One of these vessels continues beyond the others and at the tip of the stomach, leaves the latter and crosses in the mesentery to the distal end of the right lobe of the liver. Here it connects directly with a system of moderate, branching arteries on the dorsal face of the right lobe, on which it runs anteriorly. This constitutes the arterial loop which characterizes this genus.

Immediately posterior to the origin of the above vessel, a second series of arterial strands emerge from the right lobe and fuse to form a moderate vessel which runs to the head of the spleen. It branches profusely throughout this organ. About an inch beyond, a second large vessel, with a similar origin in the liver, emerges and runs to the central portion of the spleen. There are no major vessels arising posterior to this. However, on the mesial side of the right lobe, numerous small to moderate vessels emerge from the liver and cross in the mesentery to the caecal mass and to the ventral wall of the stomach. Similar small vessels nourish the straight intestine. Thus the No. II branch nourishes mainly the right lobe of the liver, the right side of the stomach, the spleen and intestine.

The No. III branch runs within the substance of the liver to the left hepatic portal vein. Here it breaks up into numerous interconnected small and moderate vessels. Some of these follow the mesial fork of the hepatic vein into the center lobe of the liver, while the others follow the lateral branch into the left lobe of the liver. In either case, these arteries run in the walls of the large hepatic veins and through extensive anastomosing they form the typical reticulations enmeshing these veins.

The separate visceral vessels arise from this branch in multiple origins which are complex and obscure. First to arise are several small vessels from the head of the liver running to the duodenal loop. Simultaneously numerous small vessels pass from the liver to the anterior portion of the adherent caecal mass. In the pyloric region several strands converge to form a large vessel which continues posteriorly on the dorsal face of the caecal mass where, through subsequent branching, it covers the posterior caecal mass with an extensive system of small arteries. From this trunk two other branches arise. One of these was found regularly. It leaves the trunk and runs in the mesentery to the ventral wall of the stomach and continues posteriorly thereon in the mid-ventral line nourishing the adjacent stomach wall to its posterior tip. The second branch is smaller and more variable in origin. It is more anterior, and arises in this major branch, or frequently in the arterial strands contributing to it, and runs in the mesentery from the caecal mass to the ventral stomach wall. Reaching this it turns anteriorly and nourishes the anterior portion of the ventral stomach wall.

Emerging from the dorsal face of the head of the left lobe of the liver is a small vessel that is typical of this genus. It arises in a multiple origin. The contributing strands fuse to form one or more small to moderate vessels which run dorsally to the left anterior wall of the stomach. On the dorsolateral face of the latter, this vessel meets several other small vessels. Of these only one was identified. This is the small median branchlet of the No. I branch. The other contributing small

vessels come from a dorsal or anterior origin. The several vessels anastomose to form a small network from which arise two separate vessels. One runs posteriorly on the left dorsolateral wall of the stomach to its tip. The other runs in the mesentery to the head of the left gonad. The latter receives, incidentally, arterial blood through two, three or more segmental vessels which enter the body cavity through the dorsal peritoneum, and run in the mesentery directly to the gonads. The No. III branch, thus nourishes the center and left lobes of the liver, the caecal mass, the duodenum, the ventral wall of the stomach and secondarily the left wall of the stomach and the left gonad.

The pattern of visceral circulation is generic. Variations were too numerous to detect any specific pattern. One gets the impression that in this species there are fewer vessels emerging posteriorly from the right lobe of the liver. Thus in *alletteratus* arteries run from the liver to the anterior and central portions of the spleen, whereas in many instances the spleen of *lineatus* receives an additional supply at its posterior extremity. However, the variations between specimens coupled with the difficulty of complete injection preclude any positive conclusions.

Cutaneous System

The cutaneous arteries originte in and perpendicular to the dorsal aorta, opposite one another in all the specimens examined. Their origin is either beneath the junction of the fifth and sixth vertebrae, or beneath the anterior portion of the sixth vertebra. They run laterally through the kidney tissue and pass consistently between the first and second ribs. At this point each artery gives rise to a small to moderate vessel which in some specimens becomes the ventral branch of the cutaneous artery. In such cases this branch is of appreciable size. In other specimens this vessel terminates in the substance of the kidney, in which case it is small and often merely one of several such small vessels nourishing the kidney. The ventral cutaneous branch will be discussed later.

Beyond the ribs the cutaneous arteries continue to the surface to emerge as the dorsal cutaneous branches in the surface musculature dorsal to the pectoral insertion. In this extent they pass between the intermuscular bones. In the slight majority of cases these vessels pass between the second and third intermuscular bones. There is, however, a wide range in this. The extreme recorded passage was between the first and second intermuscular bones, and between the fourth and fifth intermuscular bones. The two sides of the same fish are frequently different. This variation is in part attributable to errors in the count, as it is at times extremely difficult to locate the normally short first intermuscular bone which is intimately associated with the skull. On the surface, the cutaneous arteries continue posteriorly in a fairly straight course, diminishing gradually in size towards the caudal region and ending thereon in terminal branches.

Each cutaneous artery is accompanied by a dorsal cutaneous vein, which is adherent to it throughout its course. Originating in the caudal region the vein lies ventral to the artery on approximately the same surface plane until vein and artery turn axially in the pectoral region. At this point the vein crosses the external face of the artery and in

its transverse course toward the heart it lies dorsal and anterior to the still adherent artery. Within the substance of the kidney its final fate was lost, and its connection with the Cuvierian duct could not be established. The injection mass in this region was diffused through the kidney.

Both vein and artery receive or give rise to segmental vessels throughout their superficial course. These segmentals run both dorsally and ventrally. The dorsal vessels run perpendicular to the parent vessels and curve smoothly posteriorly in parallel courses. The dorsal segmental veins generally but not invariably cross the outer or lateral face of the cutaneous artery so that in an injected specimen the red of the artery is regularly interrupted by the passage of successive segmental veins. As in other species of this genus, alternate dorsal segmental arteries are generally larger and more conspicuous than the succeeding ones. Vein and artery are invariably paired and adherent.

The ventral segmental vessels follow a different course. They are directed posteroventrally at their confluence with the cutaneous vessels and run thus for about half an inch. They then angle anteroventrally, either to angle back again or branch within another half inch. The ventral segmentals are more obviously dendritic.

Both vein and artery are likewise associated in the surface musculature with capillary sheets derived respectively from relatively continuous single, somewhat irregular rows of venules and arterioles. Arterioles are closely spaced and arise roughly every 3 mm. along the cutaneous artery, with the venules similarly spaced. However the continuity is broken by occasional interspaces and the extent of these is variable in different specimens. Posteriorly both venules and arterioles are sparser. Both venules and arterioles discharge into or arise from the proximal axial face of the parent vessels. Venules tend to disintegrate immediately into capillary bundles, whereas the arterioles generally run intact for two or three millimeters and then disintegrate into capillary bundles through successive branching. Venous and arterial capillaries are interspersed, and the capillary sheet thus formed runs at first ventro-axially and then axially toward the vertebral column in several irregular planes.

The ventral cutaneous arteries are relatively small and subordinate. They contribute nothing to the above-described system, and they are actually not comparable with the ventral cutaneous branch of the Thunnidae. Regardless of their origin they invariably emerge into the surface muscles at the ventral base of the pectoral insertion, and run posteriorly directly beneath the skin in the ventral musculature as a short, relatively simple, branching system confined to the pectoral region. Vein and artery run together, but in this species the veins were not injected or investigated.

The origin of the ventral cutaneous arteries appears to be as variable as described for *yaito* and *lineatus*. The description of the latter will apply equally to this species. The ventral cutaneous may arise in the trunk of the cutaneous artery; it may arise entirely in the brachial artery, or it may be derived from contributing branches of both. On one side of one specimen the ventral cutaneous artery arose in part from the cutaneous trunk, and in part directly from the dorsal aorta.

In this case those arterioles arising from the lateral face of the dorsal aorta which flowed in the walls of the postcardinal vein, anteriorly, continued into the kidney and therein joined a network of small vessels derived mainly from the cutaneous trunks. On the other side of this fish the ventral cutaneous artery was formed by the fusion of branchlets coming from the brachial artery with a small ventral branch arising in the cutaneous trunk mesial to the ribs. Comparable variation was found in all species of this genus.

The cutaneous system of *E. alletteratus* cannot, with one possible exception, be distinguished in any detail from that of *yaito* or *lineatus*. In the initial dissections numerous detailed differences were listed, but as the work progressed each such difference disappeared as the variability of the system was discovered. The peculiarities of the cutaneous system in this case are generic.

The one possible exception is at best a relative or biometrical one. In this species the cutaneous artery and vein passed laterally on each side without exception between the first and second ribs. In *lineatus* they pass generally between the first and second ribs, whereas in *yaito*, which most closely resembles *alletteratus*, the cutaneous vessels pass in most cases between the third and fourth ribs. As this is a variable character in *yaito*, it can be used only to confirm the identification.

Postcardinal Vein

There is a large and conspicuous postcardinal vein. From the caudal region it emerges through the first completed haemal arch and flows anteriorly in the mid-dorsal line separating the two branches of the ureter. Approaching the heart it curves to the right side of the fish and indirectly discharges into the right Cuvierian duct. The actual opening of the postcardinal vein into the Cuvierian duct was not observed, as this was obscured by a complex system of perforated membranes resembling the appearance of a sponge.

At the point where the postcardinal vein emerges from the haemal canal a small renal vein, flowing anteriorly from the posterior extension of the kidney, discharges into it.

When the postcardinal vein is opened along its mid-ventral line the injected dorsal aorta can be seen running in or adherent to its dorsal wall. This view reveals also a continuous row of arterioles on each side of the aorta. These vessels arise at intervals of approximately $\frac{1}{8}$-inch or less from the lateral face of the aorta and break up into capillary bundles, some of which appear to run dorsally, while others run in the lateral walls of the postcardinal and thence into the kidney.

Between successive arterioles there is in the wall of the postcardinal a small aperture marking the entry of a venule. These apertures are arranged in a single, continuous, regular row on each side throughout the exposed extent of the postcardinal. Each aperture lies roughly between the two adjacent arterioles. These characteristic rows of venules and arterioles arising respectively in the postcardinal and dorsal aorta are common to all members of the Katsuwonidae. The postcardinal system of this species is in no way different from that of *yaito* and *lineatus*.

EUTHYNNUS

GENERIC CHARACTERS OF THE SKELETON

Cranium

Lateral View

This genus can be readily separated from all others except *Auxis*, by the dorsoposterior projection of the exoccipitals. In *Euthynnus* and *Auxis* these bones meet in the median line beneath the supraoccipital crest to form a vertical plate of bone that terminates posteriorly in an upper point. This plate, which always approximates and often meets the supraoccipital crest, may extend to, but never beyond, the junction of the skull with the first vertebra. From *Auxis*, *Euthynnus* can always be distinguished by the shape of the basioccipital. This bone in *Euthynnus* terminates posteriorly at the junction of the skull with the first vertebra, whereas in *Auxis* it extends as a distinct, long process generally to the junction of the first and second vertebra. This character is positive.

Similarly, the shape of the posteroventral outline of the cranium separates *Euthynnus* from other genera without exception. In *Euthynnus* and *Auxis* there is an abrupt angular change in the outline of the ventral margin of the skull, whereas in *Katsuwonus* and the Thunnidae this outline is rounded. In *Euthynnus* the posteroventral margin is relatively straight from the posterior ventrally projecting plate of the parasphenoid to the junction of the skull with the vertebral column. In *Auxis* the parasphenoid is produced posteriorly to form a horizontal ventral wall to the myodome, so the outline of this portion of the cranium is composed of three distinct segments. The difference is positive, and readily apparent in the illustrations. *Sarda* lacks the ventral plate of bone (parasphenoid) beneath the anterior extent of the myodome, and cannot therefore be confused with *Euthynnus*.

Dorsal View

Euthynnus differs from all the Thunnidae and from *Sarda* in having a protrusion of the free (posterior) margin of the opisthotic for the articulation of the posttemporal. It differs from *Auxis* in possessing the triangular paired apertures in the frontal bones. These, however, are quite variable, both in size and shape. It differs from *Katsuwonus* less than from any other species. All differences are relative. Of these, three in conjunction, are useful.

In *Euthynnus* the prefrontals in this view project appreciably beyond the dorsal outline of the skull, so that both can be seen simultaneously. In *Katsuwonus* the prefrontals are smaller and may reach but do not project into the dorsal outline. In the majority of specimens it is impossible to see both prefrontals simultaneously.

In *Euthynnus* the exoccipital condyle receiving the atlas projects beyond the transverse margin of the skull a distance approximately equal to the length of the first vertebra. In *Katsuwonus* this projection is much shorter, and equals roughly half the length of the first vertebra.

The sphenotics in *Euthynnus* are more expansive and project farther beyond the lateral margin of the skull than in *Katsuwonus*. However, this character is the least satisfactory of the three.

Ventral View

Euthynnus can be positively separated from all genera of the Thunnidae by the presence, in *Euthynnus*, of the protuberance on the posterior margin of the opisthotic which is conspicuous in this view. The expansive projection of the sphenotics in *Euthynnus* beyond the lateral margin of the pterotics is a corroboratory character. From the remaining genera of the Katsuwonidae, *Euthynnus* differs in the shape of the posterior orifice of the myodome which is roughly spherical in this view. In *Auxis* it resembles a greatly elongated and narrow inverted "U," whereas in *Katsuwonus* the margins are almost vertical so that little if any of the orifice is seen. Thus *Euthynnus* can be positively identified in this view.

Vertebral Column

The column of *Euthynnus* has the peculiar trelliswork characterizing the Katsuwonidae. This immediately separates it from all the Thunnidae and from *Sarda*. Since *Katsuwonus* has 41 vertebrae and *Euthynnus* 39 or less, these two genera are easily distinguished. From *Auxis*, *Euthynnus* can be positively identified because the latter has the pedicles on central vertebrae formed by both haemal processes and inferior zygapophyses. Other descriptive observations on the column of *Euthynnus* are recorded in the specific comparison. A discussion of the differences in individual bones will be found on page 167.

SPECIFIC DIFFERENCES IN THE SKELETON

The skeletons of the three described species are in general extremely similar. While there are a number of specific differences, most of these are relative with sufficient overlapping or irregularity to preclude their use as diagnostic characters. There are, however, a few positive characters which will serve to differentiate positively the species.

E. lineatus can be readily separated by two conspicuous characters. There are 39 vertebrae in the spinal column of both *E. yaito* and *E. alletteratus,* whereas there are typically 37 (36 to 38) in *E. lineatus*. Moreover, there are four conspicuous and striking symmetrical protuberances or swellings on both the 31st and 32d vertebrae in *E. lineatus*, which are lacking in *E. yaito* and *E. alletteratus*. Thus the skeleton of *E. lineatus* is positively identified. *E. yaito* and *E. alletteratus* are more similar. They can, however, be separated positively by the use of secondary characters, no one of which in itself is infallible. *E. yaito* possesses vomerine teeth, while *alletteratus* lacks them. In *alletteratus* the median dorsal crest on the skull is higher, at its lowest point, than the lateral temporal crests, while it is of the same height as the temporal crests in *lineatus* and *yaito*. These characters, in association with others, are sufficient to enable a positive identification of the skeleton of any of these species.

FIGURE 79. Dorsal view of skull of *Euthynnus*. Left to right: *lineatus*, *yaito*, *alletteratus*.

FIGURE 80. Ventral view of skull of *Euthynnus*. Left to right: *lineatus*, *pelamis*, *alletteratus*.

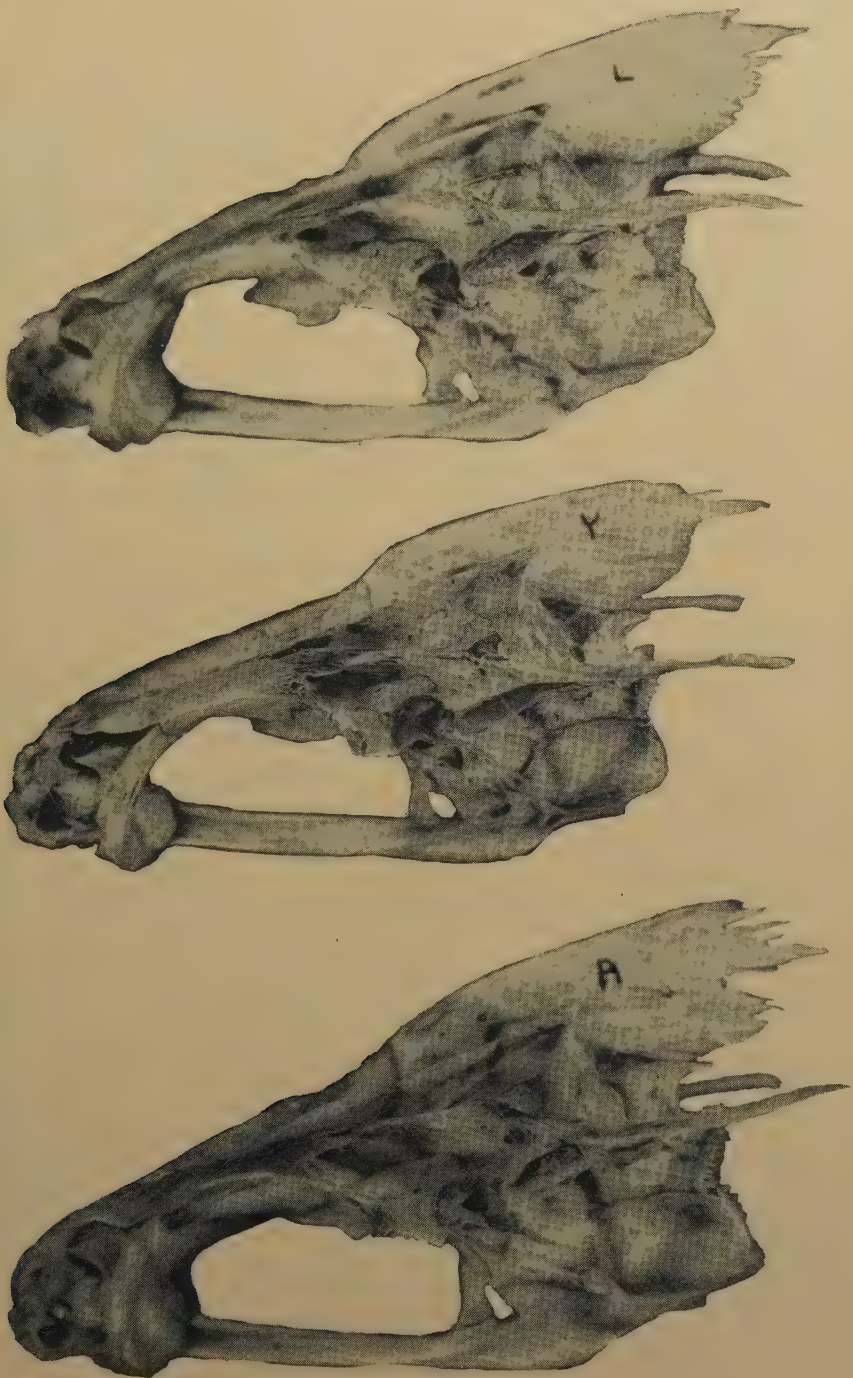

FIGURE 81. Lateral view of skull of *Euthynnus*. Top to bottom: *lineatus*, *yaito*, *alletteratus*.

Cranium

Both *E. lineatus* and *E. yaito* have vomerine teeth set into a narrow fusiform elongated basal plate, the surface of which is relatively flat and projects about one mm. from the vomer. *E. alletteratus* lacks vomerine teeth, but there is a sharp elongated projecting ridge on the vomer in place of the tooth-bearing plate. The profile view of this difference is shown in Figure 82. This difference, in the great majority of cases, will positively identify *E. alletteratus*. In this character *yaito* and *lineatus* are not distinguishable. In rare instances the tooth-bearing vomerine plate of these two species may be almost devoid of teeth and so narrow as to approach the condition in *alletteratus*. In such cases one must resort to a second indicative difference which generally, but not invariably, distinguishes *alletteratus*. The vomer of *alletteratus* is relatively flat in transverse section, whereas that of *E. yaito* and *E. lineatus* is concave ventrally. This is a relative character, but it may at times serve to corroborate the identification of specimens in which the vomerine ridge is atypical.

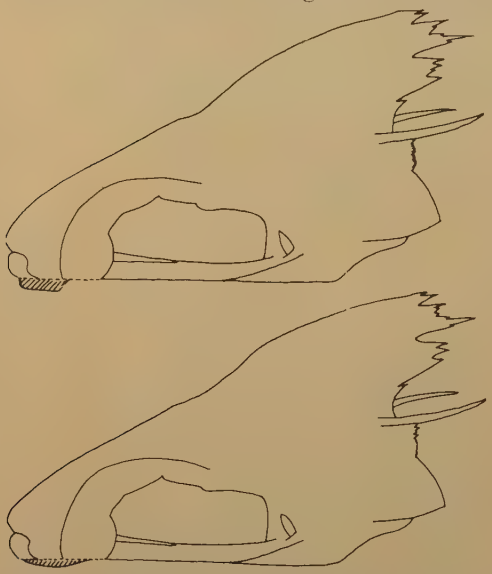

FIGURE 82. *Euthynnus:* Illustrates the difference in ventral outline of the vomerine ridge in *lineatus* (upper) and *alletteratus* (lower). *E. yaito* resembles *lineatus*.

The skull of *alletteratus* can generally be identified by a second independent character. The median ridge formed by the supraoccipital crest and the fusion of the frontals, which divides the dorsal surface of the skull, is appreciably higher at its lowest point than the horizontal plane connecting the corresponding portions of the two temporal ridges. In *lineatus* and *yaito* the median ridge is of approximately the same height at this point as the temporal ridges. The skull of the latter two species is flatter across the dorsal anterior surface. The difference can be readily appreciated and evaluated by placing the straight edge of a ruler transversely across the dorsal surface so that it lies in the deepest portion of the median foramen separating the posterior median margins of the frontal bones. A ruler so placed will rock on this median pivot in *E. alletteratus,* whereas in *E. yaito* and *E. lineatus* the ruler will generally rest on the two temporal crests. While no exceptions to the above description were found in the seven specimens of *alletteratus* examined, occasional specimens of the 29 examples of *lineatus* examined approached the *alletteratus* type.

Hence, this character is strongly indicative but not positive. Taken, however, in conjunction with the following indicative character, it invariably serves to identify *alletteratus*. This species has a broad but

FIGURE 83. Vertebral column of *Euthynnus*. Top to bottom: *lineatus*, *yaito*, *alletteratus*. Note prominent protuberances on 31st vertebra of *lineatus*, incipient ones on 33d vertebra of *alletteratus*, and complete absence of protuberances in *yaito*. The processes labeled *a* and *b* are discussed on page 165. This picture shows the anterior parapophyses arising perpendicularly in *lineatus* and obliquely in the other species. This character is variable in *lineatus* and does not distinguish this species.

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thin longitudinal bridge of cartilage which spans the median depression in the ventral median outline of the frontal bones within the orbit. This bridge was present in all specimens of *alletteratus,* and absent in all but one of *yaito.* The condition in *E. lineatus* was intermediate. In a few specimens a complete bridge was present. In a few there was a partial bridge with the middle portion incomplete, while in the remaining cases there was no trace of a bridge. There is, in the whole fish, an elastic, glistening band of tissue over this median suture of the frontal bones. In the fresh material this appears to lie against the bone, but after cleaning and drying it seems to contract and pull away from the bone and harden into the bone-like bridge under discussion. It is present in all species of *Euthynnus,* but only in *alletteratus* does it regularly separate from the bone and simulate a bridge of bone across this recess.

This association of characters affords a means of separating positively the skull of *alletteratus* from that of *lineatus* and *yaito.* The crania of the latter two species cannot be positively identified.

Vertebral Column

E. alletteratus (seven specimens) and *E. yaito* (eight specimens) have 39 vertebrae. *E. lineatus,* as a rule, has 37, and this alone will separate *E. lineatus* from the others. Of 29 specimens of *lineatus,* one had 36 and another had 38 vertebrae.

In addition to the number of vertebrae, *E. lineatus* is readily identified by the four protuberances mentioned above which occur on both the 31st and 32d vertebrae. This striking character is well illustrated in Figure 84. In a typical specimen the anterior end of the centrum of the 31st vertebra is expanded into four distinct bulbous lobes. These lobes are located laterally, dorsal and ventral, seperated by the caudal keel and the neural and haemal spines of the preceding vertebra. They are equally developed and the diameter of each is roughly half that of the centrum. The 32d centrum carries four similar bulbous lobes, but these are usually less than half the size of the preceding ones.

There is considerable variation in the extent of development of these lobes, and some variation in their location. Of 29 specimens, two had these lobes on the 30th and 31st vertebrae. Four had three series of lobes, with the regular set on the 31st and 32d vertebrae and a supplementary or partial set on the 30th vertebra. In every case the lobes on the 31st vertebra were most developed, although the others may approach them in size.

In regard to the degree of development of these lobes, every specimen dissected and subsequently examined had unmistakable lobes. In some they were small, comparable in size with the smallest lobes in the normal specimen. In others they were missing or barely developed on either dorsal or ventral side of one vertebra. Occasionally three of the four lobes on a single vertebra would be developed with the fourth absent. But in all, there was at least a partial development of unmistakable lobes on at least one of the customary vertebra. To check this character further, the writer examined the skeletal collection of C. R.

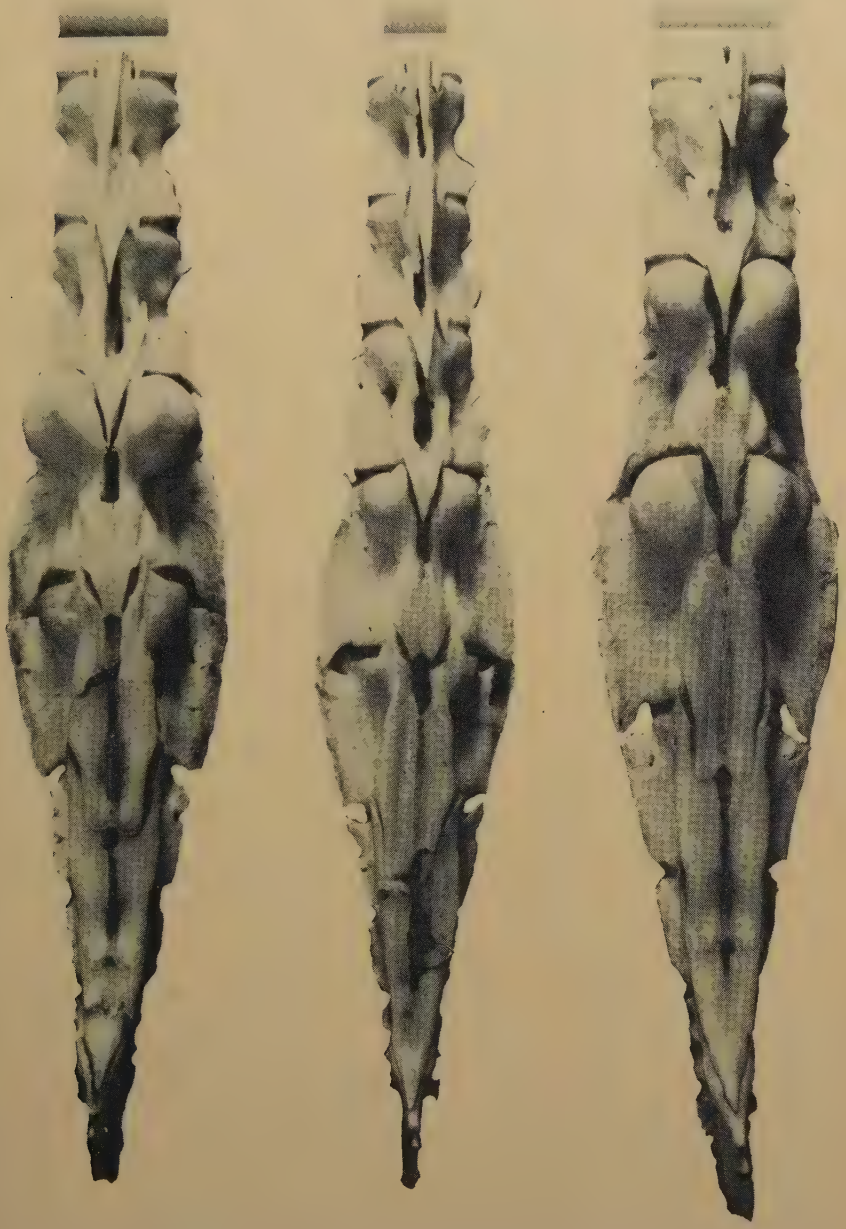


FIGURE 84. *E. lineatus:* Illustrates the variation in the location and development of the vertebral protuberances. This is a dorsal view. Comparable protuberances are present ventrally also (cf. Figure 83).

FIGURE 85. *Euthynnus:* Posterior vertebrae, to illustrate extent of development of vertebral protuberances in *yaito* (left), *alletteratus* (center), and *lineatus* (right)

Clothier. In this collection of 10 specimens, there is one broken vertebral column (with skull attached) with 37 vertebrae without a trace of these bulbous protuberances. This skeleton has one other peculiarity. All but the last three haemal spines are "S" shaped, and this is the only specimen on hand in which this is the case. In all other respects this skeleton appears identical with that of *E. lineatus*. It is therefore probable that occasional specimens may be found in which the characteristic lobes on the vertebra are entirely lacking. In this event the vertebral count must be used as the diagnostic character.

It is of interest to note that *E. alletteratus* has indications of comparable bulbous lobes on the 33d and 34th vertebrae (Fig. 85). In no specimen were any of these excessively developed, but in contrast with *E. yaito* which is entirely devoid of this structure, every specimen of *E. alletteratus* showed a uniform trace of the structures characterizing *E. lineatus*. Because this would not be apparent to the general observer, it is of value only in a detailed comparison. In such a study, however, it offers a positive means of distinguishing *E. alletteratus* from *E. yaito*.

A number of biometrical differences were also observed in the vertebral column of these three species. These observations are tabulated in Table 16. From this table it appears that in *E. lineatus* the modal occurrence of the first completed haemal arch is on the 16th vertebra, on the 17th vertebra in *E. yaito* and on the 18th vertebra in *E. alletteratus*.

There are 20 precaudal vertebrae in all species, with rare exceptions encountered in *E. lineatus*. In view of the vertebral counts there are therefore 19 caudal vertebrae in *E. yaito* and *E. alletteratus*, and 17 in the majority of *E. lineatus*.

In all species the first distinctly ventrally projecting parapophysis occurs on the ninth vertebra. There is in all species a series of processes on each side that contribute to the formation of the intricate trelliswork that constitutes the haemal canal. Two of these processes were biometrically recorded. The first process, lettered "a" in Figure 83, arises anteriorly as a branch of the haemal process, and projects ventrally. The first such definite process (neglecting minute and often threadlike spines) arose on the haemal process of the 14th vertebra in all specimens of *E. alletteratus;* on the 14th or 15th vertebra in most *E. lineatus* and on the 16th vertebra in five out of eight specimens of *E. yaito*.

Almost opposite the origin of this process a second one, lettered "b" in Figure 83, joins the haemal arch, arising in the terminal portion of the forward constituent (the inferior zygapophysis of Starks) of the pedicle on the following vertebra. This process constitutes a bridge of bone joining the pedicles of adjacent vertebrae. The first such bridge occurs on the 17th vertebra in all seven specimens of *E. alletteratus*, on the 17th vertebra in six out of eight specimens of *E. yaito*, and on the 16th vertebra in the majority of *E. lineatus* (18 out of 29).

TABLE 16

The Meristic Characters of the Vertebral Column of the Several Samples of Euthynnus. The Specimen Designated "E. y" Was Taken in Southern California Waters and Was Segregated and Separately Described Pending Positive Identification as E. yaito.

Character	*E. alletteratus*	*E. yaito*	*E. lineatus*	*E. y*
Number of vertebrae	39 (7 fish)	39 (8 fish)	36 (1 fish) 37 (25 fish) 38 (1 fish)	39 (1 fish)
1st haemal arch on vertebra No.	16 (1 fish) 18 (5 fish) 19 (1 fish)	16 (2 fish) 17 (5 fish)	15 (9 fish) 16 (13 fish) 17 (1 fish)	17 (1 fish)
Precaudal vertebrae	19 (1 fish) 20 (5 fish)	20 (5 fish)	19 (3 fish) 20 (21 fish)	
1st definite ventrally projecting parapophysis	9 (5 fish) 10 (1 fish)	8 (1 fish) 9 (7 fish)	9	9 (1 fish)
1st anterior spur on haemal spine	14 (6 fish)	15 (3 fish) 16 (5 fish)	13 (4 fish) 14 (13 fish) 15 (11 fish)	16 (1 fish)
1st haemal bridge connecting pedicles	17 (7 fish)	17 (6 fish) 18 (2 fish)	15 (2 fish) 16 (18 fish) 17 (5 fish) 18 (4 fish)	17 (1 fish)
Caudal keels mainly on	33d and 34th vert.	33d and 34th vert.	31st and 32d vert.	33d and 34th vert.

Other Bones

In addition to the cranium and vertebral column, all those separate bones were compared which were available in sufficient numbers. In none were positive and invariable differences found. Many bones differed relatively, but in every case there was either sufficient overlapping or a sufficient number of exceptions to invalidate their use as diagnostic characters. They are listed below as indicative characters in order to record the findings. No differences were observed in the following: operculum, interoperculum, subopercular, preopercular, pelvic girdle, palatine, mesopterygoid, epihyal, ceratohyal, maxillary, dentary, supraclavicle, auxiliary maxillary, urohyal, clavicle.

The hyomandibular and metapterygoid appeared to differ upon first inspection. When, however, the comparison was extended to several specimens of each species, the differences were resolved. A genuine difference appears to exist in the pterygoid. Looking at the ventral view of this bone in its normal position, there is a distinct and pronounced curve or bulge in the lateral margin of the horizontal portion in *E. yaito*, whereas the margin in *E. alletteratus* and *E. lineatus* is relatively straight. Exceptions were found in the case of *E. lineatus*, where in occasional specimens the condition resembled that of *E. yaito*. Hence this character is confirmatory rather than diagnostic.

The posttemporal of *E. alletteratus* appears proportionately narrower and more slender than that of *E. yaito* and *E. lineatus*. The proportions were not biometrically investigated. *E. lineatus* and *E. yaito* appeared to resemble each other in this character.

The articular bone of *E. alletteratus* is in the majority of cases separable from those of *E. yaito* and *E. lineatus*, in which the condition is the same. The articulating facet at the posterior end of the bone is distinctly curved upward in the latter two species, resembling an open hook. In *E. alletteratus* the hooked appearance is lacking, and the dorsal margin is only gently curved. There are exceptions to this, and the character is only an indicative one.

There is a suggestive but variable difference in the premaxillary. The one or more foramen at the anterior internal angle of this bone are recessed in a relatively deep crescentic depression in most specimens of *E. alletteratus*, whereas in *E. yaito* and *E. lineatus* this depression is generally lacking, and the foramen are more superficial. Moreover, the foramen—or one of the two—in the depression of *E. alletteratus* is conspicuously larger as a rule than in *E. lineatus* or *E. yaito*.

As in many of the other platelike bones, the preorbital of *E. yaito* appears to be more compact and proportionately wider than that of the two other species. This bone is intermediate in *E. lineatus* and most slender in *E. alletteratus*. There is a consistent tendency for this bone to curl, and it was not practical to obtain good measurements of its dimensions.

The lower portion of the postclavicle (Kishinouye, page 333) appeared to differ in several specimens of *E. alletteratus*. The extremely attenuated spine-like portion of this bone arises in a ridge of the lamellar portion. At its origin this ridge, in *E. alletteratus*, is higher and more precipitous than in the other species. There are, however,

TABLE 17

A Tabular Comparison and Evaluation of Suggestive Differences in Three Species of Euthynnus

Character	*E. lineatus*	*E. alletteratus*	*E. yaito*	Nature of difference
A. EXTERNAL:				
Dorsal markings	Continuous, horizontal bars	Broken horizontal bars	Broken oblique bars	Indicative
Color	Darker or deeper hued than in *alletteratus* or *yaito*	As in *yaito*	As in *alletteratus*	Relative
Belly spots	Larger than in *yaito*	Not recorded	Consistently smaller than in *lineatus*	Relative
Lateral line	a—dip below second dorsal	No dip below second dorsal	No dip below second dorsal	Indicative
	b—relatively steep rise above pectoral	Gentle rise above pectoral	No pronounced rise above pectoral	Relative
Vomerine teeth	Present	Absent	Present	Positive
Maxillary extent	To vertical through center of eye	As in *lineatus*	To or beyond vertical through center of eye	Indicative
Proportions:				
Head length	3.13 to 3.62 as in *yaito* longer than *alletteratus*	3.65 to 3.89 shorter than *yaito* and *lineatus*	3.44 to 3.60 as in *lineatus* longer than *alletteratus*	Biometrical
Insertion-first dorsal	2.82 to 3.33 more posterior than *alletteratus*, as in *yaito*	3.37 to 3.55 more anterior than in *yaito* and *lineatus*	3.11 to 3.23 as in *lineatus* more posterior than in *alletteratus*	Biometrical
Insertion-second dorsal	1.51 to 1.79 includes *yaito* and *alletteratus*	1.72 to 1.77 as in *lineatus* more anterior than in *yaito*	1.65 to 1.70 as in *lineatus* more posterior than in *alletteratus*	Biometrical
Insertion-Anal fin	1.37 to 1.55 as in *yaito* more posterior than in *alletteratus*	1.57 to 1.61 more anterior than in *yaito* and *lineatus*	1.48 to 1.52 as in *lineatus* more posterior than in *alletteratus*	Biometrical
Insertion-Ventral fin	2.76 to 3.25 as in *yaito* more posterior than in *alletteratus*	3.27 to 3.46 more anterior than in *yaito* and *lineatus*	3.07 to 3.24 as in *lineatus* more posterior than in *alletteratus*	Biometrical
Ventral insertion to vent	2.62 to 3.01 includes *yaito* and overlaps *alletteratus*	2.57 to 3.12 overlaps *lineatus* less than *yaito*	2.75 to 2.95 as in *lineatus* greater than *alletteratus*	Biometrical
Width between anterior margin of eye	Less than distance from tip of upper jaw to plane through anterior margin of eye	Less than distance from tip of upper jaw to plane through anterior margin of eye	Greater than distance from tip of upper jaw to plane through anterior margin of eye	Biometrical
Gill rakers	7 to 10: 1 : 24 to 28 Total count 33 to 39	10 to 11: 1 : 26 to 28 Total count 37 to 40	7 to 8: 1 : 22 to 24 Total count 29 to 33	Biometrical
Gill teeth	8 to 10: 21 to 23 Total count 29 to 31	9: 22 to 23 Total count 31 to 32	8: 20 to 21 Total count 28 to 29	Biometrical
Anal rays	11 to 12	11 to 15	13 to 14	Biometrical

B. INTERNAL:				
Ventral view of viscera				
1. Mosaic	Absent	Absent	Present, generally	Indicative
2. Right lobe of liver	Lateral, as in *yaito*	Mesial	Lateral, as in *lineatus*	Doubtful
3. Fat organ	Absent	Absent	Present, generally	Indicative
Ureter				
1. Branches	Large, straight, few collecting tubules as in *yaito*	Generally small, erratic, numerous collecting tubules	Large, straight, few collecting tubules as in *lineatus*	Relative—Questionable
C. SKELETON:				
Vertebral column	37 vertebrae	39 vertebrae	39 vertebrae	Positive
Protuberances	4 large lobes on each, 31st and 32d vertebrae	Incipient lobes on 33d and 34th vertebrae	No trace	Positive
Caudal keels mainly on	31st and 32d vertebrae	33d and 34th vertebrae	33d and 34th vertebrae	Positive
Cranium	1. Dentigerous plate on vomer as in *yaito*	Sharp longitudinal ridge on vomer	Dentigerous plate on vomer, as in *lineatus*	Positive
	2. Supraoccipital crest at lowest point in same horizontal plane as temporal crests, as in *yaito*	Supraoccipital crest at lowest point appreciably higher than temporal crests	Supraoccipital crest at lowest point in same horizontal plane as temporal crests, as in *lineatus*	Relative
	3. Intermediate between *yaito* and *alletteratus*	Longitudinal bridge of bone (see page 162) present in orbit	Longitudinal bridge of bone in orbit, absent	Relative

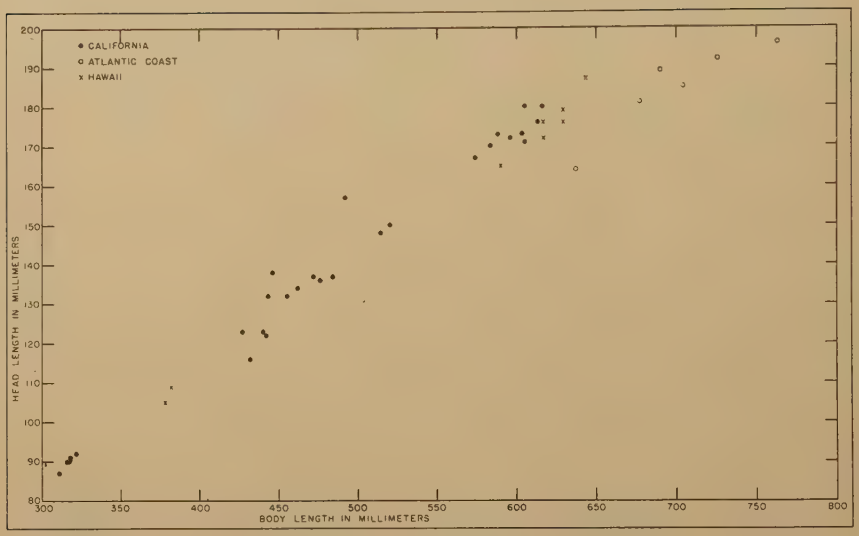


FIGURE 86. *Euthynnus:* The regression of head length on body length in *lineatus, yaito* and *alletteratus*

exceptions to this. The lamellar portion of this bone, or at least the throat of this portion, appears to be narrower in the majority of specimens of *E. lineatus* when compared to the two other species. These differences are relative, and have little diagnostic value.

The upper element or piece of the postclavicle tends to differ in shape. The broader extremity of this bone is more rounded in *E. yaito* and lacks the tendency found in the two other species to form a short, blunt terminal projection.

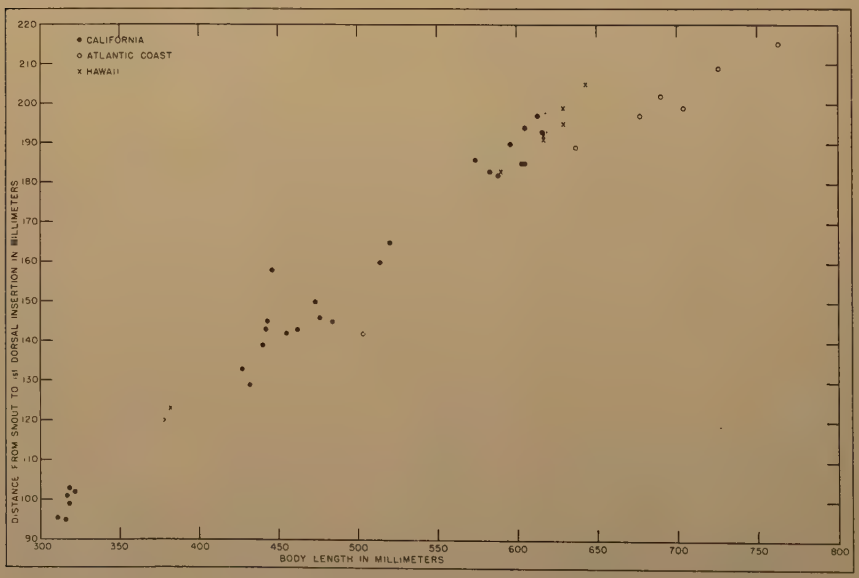


FIGURE 87. *Euthynnus:* The regression of first dorsal insertion on body length in *lineatus, yaito* and *alletteratus*

The glossohyal changes its proportions with increasing size of fish. Because of this, and because many of these elements were lost in cleaning and subsequent handling, insufficient material was available for positive conclusions. However there are indications subject to confirmation that the glossohyal of *E. yaito* differs in shape from that of *E. lineatus* and of *E. alletteratus*. In the two species the lateral margins of this bone were roughly parallel and the greatest width generally occurred near the proximal end. In *E. yaito* the tongue was more bell-shaped, and the greatest width was at the extreme distal end.

The above differences are relative, variable and at best indicative. They are discussed merely to record the findings. They cannot be used as diagnostic characters because individual specimens may contradict the foregoing generalizations.

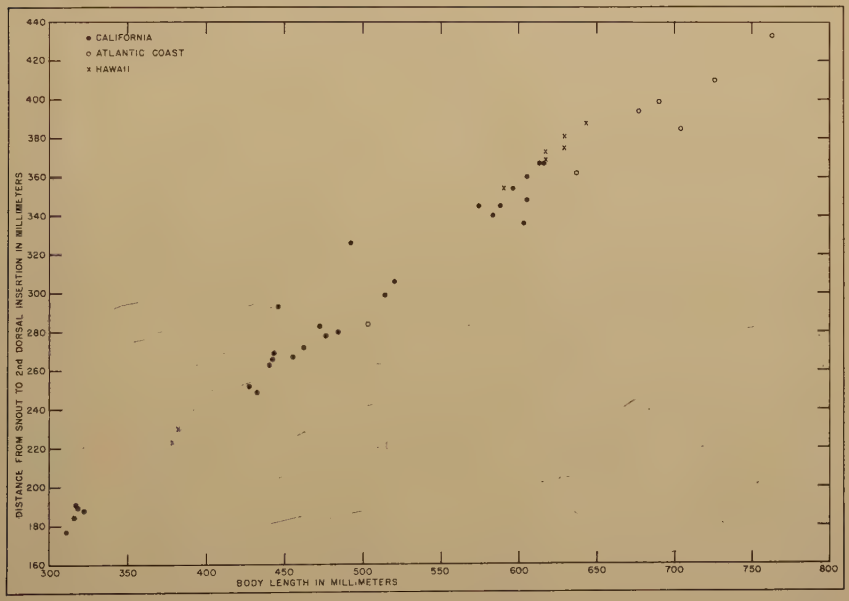


FIGURE 88. *Euthynnus:* The regression of second dorsal insertion on body length in *lineatus*, *yaito* and *alletteratus*

A COMPARISON OF THE THREE SPECIES

As an aid in digesting the present findings, those characters that appear consistently or appreciably different in any species are listed in Table 17.

While the specific identity of these three forms appears to be well established in fact, the numerous differences that distinguish each are mostly relative. In the foregoing list, there are surprisingly few characters listed as "positive." Moreover, at least some of these would probably become relative when tested against larger numbers of specimens. It will be noted also that all the positive characters pertain to the skeleton. Of these only the absence of dentigerous vomerine plate in *E. alletteratus* can be used in superficial identification. The definition

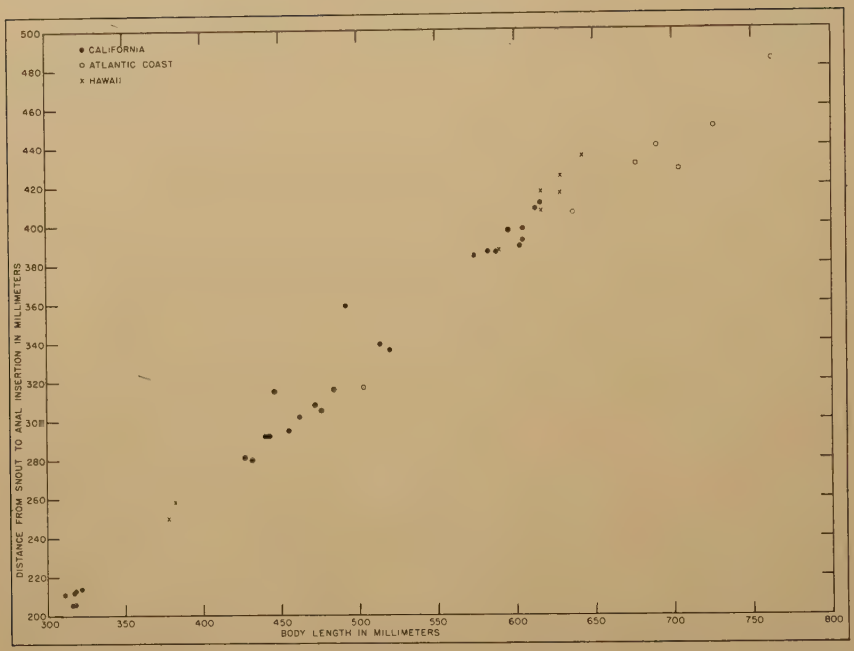


FIGURE 89. *Euthynnus:* The regression of anal insertion on body length in *lineatus, yaito* and *alletteratus*

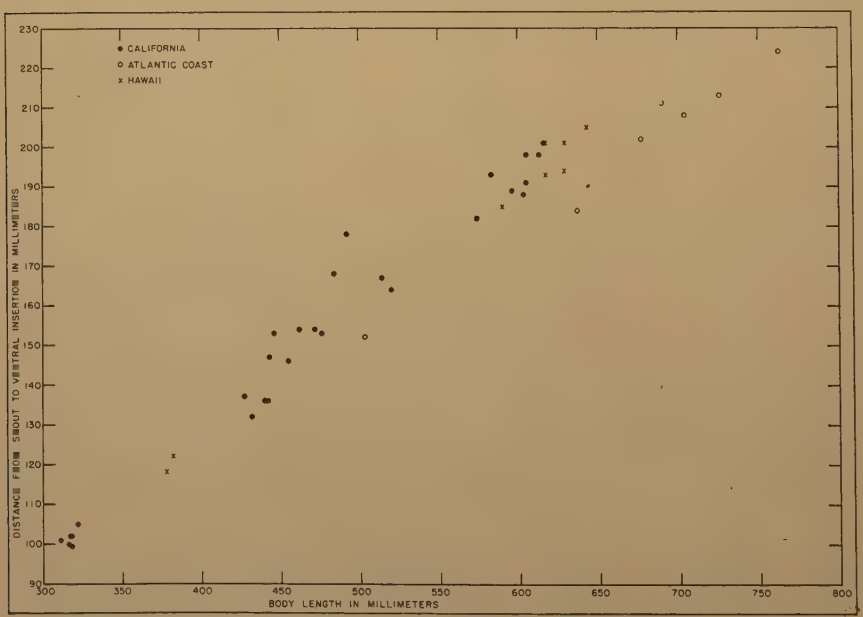


FIGURE 90. *Euthynnus:* The regression of ventral insertion on body length in *lineatus, yaito* and *alletteratus*

of the species must be based on the positive skeletal differences, and lacking positive external characters, the superficial indentification must necessarily depend on an assemblage of relative characters, subject to final confirmation by the basic skeletal differences.

E. lineatus is clearly differentiated by the possession of 37 (36-38), instead of the customary 39 vertebrae. It is further differentiated from the remaining species by the presence of the four characteristic lobes on each of two vertebrae, the thirty-first and thirty-second, and by having the major portion of the caudal keels on these two vertebrae instead of on the thirty-third and thirty-fourth vertebrae as in *yaito* and *alletteratus*. Superficially these characters of *lineatus* are associated in the majority of specimens with relatively straight, horizontal black bars above the lateral line; with a wavelike and frequently steep rise in the lateral line above the pectoral; with a combined count of 33 to 39 gill rakers on the first arch; with a combined count of 29 to 31 gill teeth on the same arch and with 11 or 12 anal rays. The list of corroboratory characters can be extended from the above tabulation.

E. alletteratus and *E. yaito* are basically similar. Both have 39 vertebrae. They are specifically different in only minor structural features. Of these the absence of vomerine teeth in *alletteratus*, the presence of incipient lobes on the thirty-third and thirty-fourth vertebrae in *alletteratus* and their absence in *yaito*, and the relative differences in the cranium of the two are the differences upon which the species must rest. Superficially these are associated with the corroboratory and relative differences tabulated above. Thus the superficial identification of these two species could be made by the presence or absence of vomerine teeth, corroborated by the broken oblique dorsal markings in *yaito* and the broken horizontal markings in *alletteratus;* by the presence of 37 to 40 gill rakers and 31 or 32 gill teeth on the first arch of *alletteratus*, compared with 29 to 33 rakers and 28 or 29 gill teeth in *yaito*, and by the several biometrical differences listed in the table.

Concerning the latter differences, of which there are several separating *yaito* from *alletteratus*, the author is opposed to the indiscriminate use of such characters for the purpose of splitting species. Such proportionate differences are functions of the size of the specimen, of the

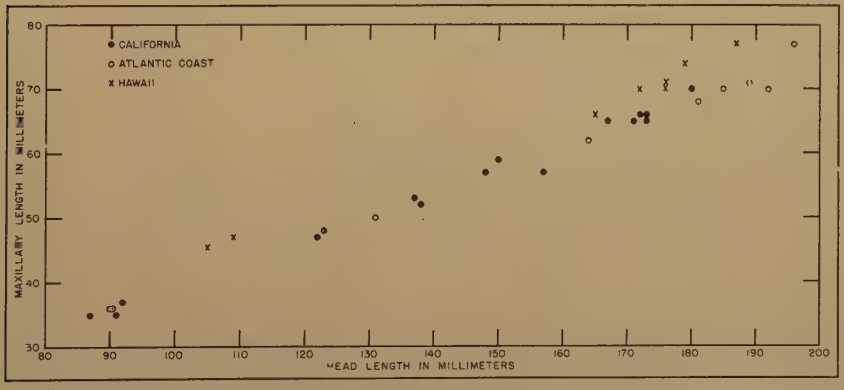


FIGURE 91. *Euthynnus:* The regression of maxillary length on head length in *lineatus, yaito* and *alletteratus*

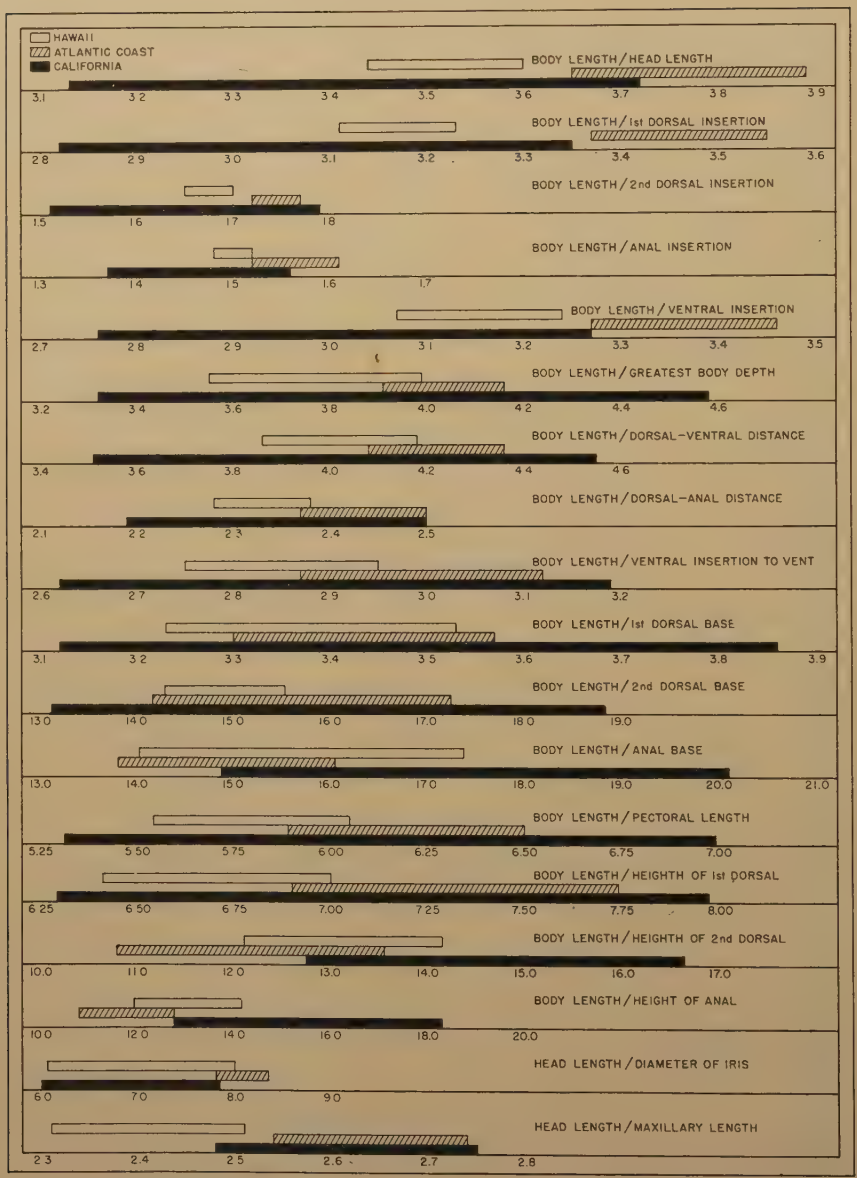

HAWAII
ATLANTIC COAST
CALIFORNIA
BODY LENGTH / HEAD LENGTH
3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9
BODY LENGTH / 1st DORSAL INSERTION
2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.6
BODY LENGTH / 2nd DORSAL INSERTION
1.5 1.6 1.7 1.8
BODY LENGTH / ANAL INSERTION
1.3 1.4 1.5 1.6 1.7
BODY LENGTH / VENTRAL INSERTION
2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5
BODY LENGTH / GREATEST BODY DEPTH
3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6
BODY LENGTH / DORSAL–VENTRAL DISTANCE
3.4 3.6 3.8 4.0 4.2 4.4 4.6
BODY LENGTH / DORSAL–ANAL DISTANCE
2.1 2.2 2.3 2.4 2.5
BODY LENGTH / VENTRAL INSERTION TO VENT
2.6 2.7 2.8 2.9 3.0 3.1 3.2
BODY LENGTH / 1st DORSAL BASE
3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9
BODY LENGTH / 2nd DORSAL BASE
13.0 14.0 15.0 16.0 17.0 18.0 19.0
BODY LENGTH / ANAL BASE
13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0
BODY LENGTH / PECTORAL LENGTH
5.25 5.50 5.75 6.00 6.25 6.50 6.75 7.00
BODY LENGTH / HEIGHTH OF 1st DORSAL
6.25 6.50 6.75 7.00 7.25 7.50 7.75 8.00
BODY LENGTH / HEIGHTH OF 2nd DORSAL
10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0
BODY LENGTH / HEIGHT OF ANAL
10.0 12.0 14.0 16.0 18.0 20.0
HEAD LENGTH / DIAMETER OF IRIS
6.0 7.0 8.0 9.0
HEAD LENGTH / MAXILLARY LENGTH
2.3 2.4 2.5 2.6 2.7 2.8

FIGURE 92. *Euthynnus:* The range in the ratios of the respective measurements to either body length or head length in *lineatus, yaito* and *alletteratus*

number of specimens examined, of the condition of the specimens and of the distribution of the species. Thus, measurements made upon freshly caught fish will differ appreciably from duplicate measurements made upon the same fish after prolonged cold storage or preservation in liquid. Proportions change appreciably with increase in size of specimen (Figures 86-91), so that such measurements must either be made upon fish of strictly comparable size, or be treated as regressions. Fish unquestionably of the same species may be regionally localized into distinct populations, and such populations are frequently distinguishable—collectively—in a biometrical analysis by slight differences in modal body proportions. Similar remarks apply to meristic counts. Although these facts are trite and obvious, a good deal of confusion in the literature has resulted by their oversight. There is nothing to be gained by an erroneous creation of species.

In many of the proportions (Figure 92) *yaito* differs slightly from *alletteratus*. In most of these cases the resulting ratios are lower for *yaito* because the head is proportionately larger and the fins are more posteriorly inserted. While these differences are individually small, they are all in the same direction. If the measurements or ratios of such characters are summed, the resulting figures yield an index of these characters in the species. Thus, summing the five ratios resulting from the division of body length in each case by head length, first dorsal insertion, second dorsal insertion, anal insertion and ventral insertion, results in a figure ranging from 12.86 to 13.23 in eight specimens of *yaito*, and from 13.64 to 14.19 in seven specimens of *alletteratus*. Moreover the distribution of these values is apparently independent of the size of the fish, so that a mean value can be used to define the species. The two means are 13.046 for *yaito* and 13.996 for *alletteratus*, with standard deviations of 0.1675 and 0.162 respectively. As these values and distributions are quite distinct the expedient may possess some value as a corroboratory character in separating species.

Before concluding this discussion of biometrical characters, it is advisable to call attention to the large range in the distribution of measurements in the case of *lineatus*. In almost every case this is excessively greater than the corresponding range for *yaito* and *alletteratus*. The writer's explanation of this is that *lineatus* and *yaito*—at least—appear to be localized in distribution. The writer's experience on the west coasts of Baja California and Central America suggests that *lineatus* is confined to certain inshore areas and is not, as in the case of the skipjack and yellowfin tuna, widely and continuously distributed over this entire extent. Again, fishing in the Hawaiian Island group the writer noted that *yaito* appeared to be confined to within the 20 or 30 fathom contour. Invariably *Euthynnus* predominated in the troll catch in shallow water around reefs, banks or points, but as fishing progressed into deeper water the catch of *Euthynnus* fell off and *Katsuwonus* and *Neothunnus* displaced it. Beyond—roughly—30 fathoms no specimens of *Euthynnus* were caught. This suggests that the stock of *Euthynnus* may be relatively localized geographically.

The specimens of *lineatus* came from a great expanse. They were taken from Baja California to and beyond the Galapagos Islands. It is

probable that there may be within this total extent localized and non-intermingling populations characterized by slight biometrical differences. The sample at hand is a mixed one, with representatives from several of these areas or stocks. If they actually differ slightly in bodily proportions, one would expect a greater range in composite samples. This emphasizes earlier remarks concerning the uncritical use of proportions in species differentiation. Slight differences in proportions in individual specimens do not, in the writer's opinion, constitute a valid basis of species separation.

A utilitarian key for the separation of these species of *Euthynnus*.

A: Specimens having 37 (36-38) vertebrae, with four lobes or protuberances on each of the two vertebrae, predominantly the 31st and 32d. (Invariably has vomerine teeth: usually has about five continuous, horizontal black dorsal stripes: 33-39 gill rakers and 29 to 31 gill teeth: other corroboratory characters listed in summary: distribution not fully known: occurs commonly in eastern Pacific inshore along the coasts of North and Central America and Northern South America.)

lineatus

B: Specimens having 39 vertebrae.

1. Vomerine teeth present. No indication of lobes on 33d or 34th vertebrae. (Usually has oblique broken dorsal markings: from 29 to 33 gill rakers and 28 or 29 gill teeth; width of snout between anterior margin of eyes greater than distance of this plane from tip of upper jaw, subject to confirmation; sum of ratios: body length divided by head length, first dorsal, second dorsal, anal and ventral fin insertions, 12.86 to 13.23, mean 13.046: other corroboratory characters in text: distribution: described from the western tropical and lower temperate Pacific. Extent of distribution unknown. Occurs commonly in the Hawaiian group, and at least one specimen has been taken off Southern California.)

yaito

2. Vomerine teeth absent, although a longitudinal bony ridge can be felt in this area. Incipient lobes or protuberances occur on the 33d and 34th vertebrae. (Usually has broken horizontal dorsal markings: from 37 to 40 gill rakers and 31 or 32 gill teeth: width of snout between anterior margin of eyes less than distance of this plane from tip of upper jaw: sum of ratios: body length divided by head length, first dorsal, second dorsal, and anal and ventral fin insertions, 13.64 to 14.19, mean 13.996: other corroboratory characters in text: distribution: total extent not known: common on southern Atlantic coastline of United States.)

alletteratus

RELATIONSHIPS OF THE TUNAS AND TUNA-LIKE FISHES

It is presumptive to discuss the relationship of the members of this group without a thorough knowledge of all related species, which the writer admittedly does not possess. However, I shall attempt to present those facts that have emerged from my observations.

The problem of separating and defining those species discussed in this and my earlier papers is not difficult. The species are well defined regardless of opinions on nomenclature, and, with the exception of *Sarda*, fall readily within one of two groups. The tunas proper, including *Thunnus*, *Neothunnus* and *Parathunnus*, have certain characters in common which set them apart from the remaining species. Thus, they are all completely covered with scales; all have a folded intestine; all have the spleen ventral to the stomach so that it is conspicuous in ventral view; and all have in common certain characteristics of the skull.

The remaining genera of tuna-like fish, namely, *Katsuwonus*, *Euthynnus* and *Auxis*, likewise fall into a second well defined group. All have a straight intestine (without a fold in it); all are devoid of scales except in the head and pectoral region; all have the ventral processes of the vertebrae developed (more or less) into a characteristic trellis-work; all have the spleen dorsal and lateral to the stomach so that it is completely concealed in ventral view, and all have characteristics of the skull peculiar to the group.

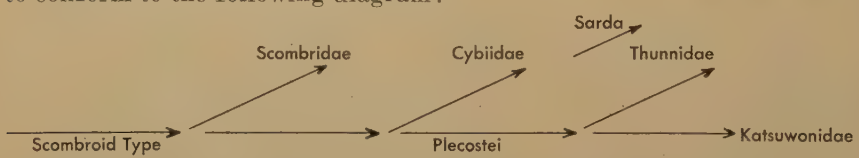
These two groups of fish are not only well defined, but they are relatively homogeneous. The degree of fundamental similarity within each group implies a close relationship of the included genera. Such groupings of closely related genera are, for convenience, classed as a family. Kishinouye, impressed by these relationships, separated the tunas proper (*Thunnus*, *Neothunnus* and *Parathunnus*) into the family Thunnidae, and all the remaining tuna-like fish, *Katsuwonus*, *Euthynnus* and *Auxis*, into the family Katsuwonidae. The writer's findings fully support this view. Whether or not the term family should be used is a matter of opinion; but regardless of the term applied to a group, these two are valid assemblages of genera more closely related within the group than to anything without it. Because such an assemblage of related genera is customarily called a family, the writer endorses the opinions of Kishinouye, and will consider each group as a family.

The two families, Thunnidae and Katsuwonidae, although alike in external form, in certain skeletal structures and in the pattern of the circulatory system, are in the majority of anatomical characters quite different. However, they share two characters which are unique. In every species within the two families all individuals have a deep recess in the ventral surface of the skull separating the pterotic bone from the brain case. This will be designated, for convenience, the prootic pit. No other scombroid species has this character.[4]

[4] *Sarda*, which possesses an incipient saucer-like prootic pit does not constitute an exception, because this depression is in no way comparable in development with that of the Plecostei.

Every species within the two families possesses a complex system of cutaneous blood vessels such as are found in no other living fish. These two unique characters superficially suggest an intimate relationship between the two families, and imply a common descent. On the basis of the cranial structure alone Starks (1910) separated the genera of these groups from all other scombroid fishes and placed them collectively into the subfamily Thunninae. On the basis of both characters Kishinouye independently raised Starks' subfamily to the rank of a separate order, the Plecostei, and created the family Thunnidae to express the intrinsic relationship of *Thunnus*, *Neothunnus* and *Parathunnus*, and the family Katsuwonidae to emphasize the relationship of *Katsuwonus*, *Euthynnus* and *Auxis*. The significance of this lies in the fact that these two workers who have made, respectively, detailed studies of the skeleton of the scombroid fish and the most comprehensive study of their entire anatomy, agree essentially in the basic interrelationships.

This conclusion is based principally, however, upon one or two characters selected because of their uniqueness. If the relationship so traced is valid, then all, or at least the majority of, other stable characters should fit into this interpretation. This, however, is not the case. In particular, the characters of *Sarda* conflict. On the assumption that the Thunnidae and Katsuwonidae are more alike and are therefore more intimately related to one another than to any other group, one would expect to be able to trace the characters of *Sarda* to a point on the evolutionary branch earlier or antecedent to the specialized origin of the tunas. Graphically, one would expect all significant characters to conform to the following diagram:



Instead of this, one finds that *Sarda* in many significant characters falls between the Thunnidae and Katsuwonidae. In fact if one selected different characters to indicate the relationships and hence the origin of the various groups, one can derive an entirely different diagram. Because the evidence of descent is incomplete, and the true relationships are obscure, one's convictions or interpretations depend largely upon the significance attached to particular characters. Both Kishinouye and Starks were strongly influenced by the unique characters common to the two families, and hence arrived at the same general conclusion. Both, however, were aware of and troubled by the position of *Sarda* in the resulting scheme. Kishinouye refers frequently to the similarity of *Sarda* to the Thunnidae, and Starks (p. 81) expressed his doubts as follows: "The exact position of *Sarda* is a little obscure. It has the concave ethmoid and nonprojecting nasals of *Scomberomorus* and *Acanthocybium*, but has the cranial crests arranged almost identically as in the Thunninae. On the lower surface of the cranium is a slight depression showing a development towards the deep pit of the Thunninae and the caudal peduncle has a lateral keel. Consequently

it must have sprung from somewhere between the Scomberominae and the Thunninae to have such marked characters of both groups. It shows, however, a much closer alliance with the latter sub-family than with the former."

Although the cutaneous system and the prootic pit are unique and striking characters, there are in reality others that are probably of equal significance. One such character has apparently been overlooked although Allis (1903) described it in *Scomber*. Mr. S. Imamura discovered this while examining the skeletons of the several species. In all species of the Katsuwonidae, and in the mackerel *(Pneumatophorus)* the neural canal in the first few vertebrae is divided horizontally into two separate compartments. The spinal cord runs in the lower compartment, contiguous with the centra, while an elastic ligamentous cord runs above it in the upper separated portion of the canal. In the Thunnidae, in *Sarda*, in *Acanthocybium* and in *Scomberomorus* the neural canal is not so divided, and the ligamentous cord runs with the nerve in the same canal. Uncritically, this character of itself, relates the Katsuwonidae to the mackerel, and the Thunnidae to the Cybiidae of Kishinouye.

Similarly, the location of the spleen suggests a different relationship. Within a species the position of the spleen is constant and invariable, and the writer was equally impressed by this character. It is certainly no coincidence that in all the Katsuwonidae and in the mackerel the spleen is located dorsal and lateral to the anterior portion of the stomach so that it is entirely and invariably concealed in the ventral view of the viscera, *in situ*. In striking contrast, the spleen in all members of the Thunnidae and in *Sarda* is invariably located ventral to the stomach (and in part ventral to the intestine) so that it is a conspicuous part of the ventral view of the viscera. This character may be as unique as the prootic pit, because one gathers from a study of Kishinouye's descriptions that the spleen is concealed in all the remaining Cybiidae. Therefore, this character taken in conjunction with the neural canal would segregate the bonito and the Thunnidae into one related group, leaving the Katsuwonidae in a group with the mackerel. As long as all characters do not accord with a scheme of classification, it is obvious that a resultant classification will depend upon the particular characters used, which in turn will depend upon the author's evaluation of specific characters.

The writer has attempted unsuccessfully to fit the total assemblage of characters into an orderly pattern of relationship. When this attempt is confined to the two families Katsuwonidae and Thunnidae, the problem is simple and one can readily reconstruct in several alternate ways the divergence of the two families from a common origin. When, however, one attempts to fit *Sarda* into this picture, this genus inevitably (in any combination of fundamental characters) falls between the two families. To illustrate this, an array of significant positive characters has been made in Figure 93. In this tabulation each character listed has been reduced to a positive alternative, and characters involving a progressive relative difference have, for the most part, been omitted. Moreover, the characters have been arranged so that those common to a majority of the groups are at the left. In this list is one character not hitherto mentioned. In the Thunnidae the ventral margin of the

FIGURE 93. A graphical comparison of various characters in the four groups discussed. In each column identity in shading represents similarity in the character.

prootic bone connects a ventral portion of the parasphenoid with the sphenotic, thus forming a continuous, slightly oblique transverse ridge from the parasphenoid to the lateral margin of the skull. In the Katsuwonidae this ridge is interrupted or discontinuous, because the prootic does not completely bridge the gap between the parasphenoid and sphenotic.

The problem of discerning affinities and tracing descent immediately becomes apparent. *Sarda* resembles the Thunnidae in more characters than does the family Katsuwonidae. In many respects it appears to fall between the two families. Based upon identity or similarity in the total assemblage of characters, the writer finds it impossible to derive a lineage for *Sarda* separate from that of the Thunnidae. In anatomical design *Sarda* shows a strong resemblance to both this family and the Katsuwonidae, and it can be linked to either in specific characters.

In the attempt to establish genetic relationships, one is faced with two major alternatives. If one accepts unique characters, i.e., the prootic pit and the cutaneous system, as the primary criteria of a common ancestry, then there can be little doubt as to the exclusive relationship of the Thunnidae with the Katsuwonidae, and the separation of these two families into a single superfamily or group is fully warranted. Under this alternative the order Plecostei (or some equivalent group) of Kishinouye is fully justified. If, however, all characters are considered without weighting the two foregoing, one must conclude that the families Katsuwonidae and Thunnidae are two distinct units within a larger group and that the bonito is related to both families as closely as the latter are to one another. Under this alternative the families Katsuwonidae and Thunnidae are clearly differentiated by the present findings, but the inclusion of both in a separate and distinct order or super group separated from the Cybiidae is not justified.

Working with these species, one acquires a subjective, intuitive feeling of relationship based upon the aggregate of observations. Though such feelings may amount to a conviction, they are not easy to substantiate. The following brief discussion will attempt to convey the reasons for favoring the second alternative.

The cutaneous system, which is such a striking and unique character of these two families, has obviously not arisen as a spontaneous and complete manifestation. It has evolved through untold generations, step by step, probably from a single segmental artery to the surface musculature. In such a segmental one can see the incipient origin of a cutaneous artery in the bonito, or for that matter in a mackerel. Thus in *Pneumatorphous* there is, in lieu of a cutaneous artery a vessel arising in the same region on each side, just posterior to the brachial artery, which runs into the kidney towards, but not reaching, the surface. In *Sarda* the second segmental posterior to the brachials runs towards the pectoral fin. In the Katsuwonidae one sees the consummation of a cutaneous system with a variable origin. In *Auxis*, dorsal and ventral branches arise separately in the aorta. In *Euthynnus* the origin of the ventral branch is variable and unstable. Associated with the origin of the cutaneous arteries is the fact that the entire arterial system becomes profusely, even erratically diversified. It suggests that the causative factors had resulted in an entire dislocation of the arterial system which tends to break up dendritically throughout. In the Thunnidae this has

apparently evolved into a stable pattern, but in the Katsuwonidae one feels that an ebullient natural experiment is still in process, and that the origin of this cutaneous system is quite recent. Of this profusion the present species represent the transitory survival of countless variants. The earlier stages in the evolutions of this system have been entirely obliterated. Moreover there is no valid reason to assume that this arterial eruption is limited in time. If the incipient cutaneous system, and the potential of its development, were widespread in a broad group of related species, there is no reason to preclude a manifestation of this potential at various epochs in evolutionary history. It seems probable that the cutaneous system of the Katsuwonidae is a much more recent manifestation than that of the Thunnidae. In this case it does not necessarily imply an identical origin.

Concerning the prootic pit, acceptance of this as a primary evolutionary criterion would necessarily relate the Katsuwonidae more closely to the Thunnidae than to any other group. It is an unique character. The only thing remotely comparable (in the writer's experience) is found in *Sarda*. Here a shallow saucer-like depression suggests its incipient origin. On the basis of this character—in living forms—both the Katsuwonidae and Thunnidae must have sprung from the *Sarda* stock, or its progenitor. However, as with the cutaneous system, it is quite possible that a developing prootic pit was prevalent in now defunct links in the evolutionary chain. If such were so, the Thunnidae and Katsuwonidae could have sprung from different twigs of the same branch. Likewise it is possible—though admittedly speculative—that the prootic pit may be associated with the development of the cutaneous system. It is certainly a coincidence that both characters are unique, and that one does not occur without the other.

In the course of this work, the writer was impressed by the similarity of *Auxis* in certain characters with the mackerel. Apart from the external likenesses resulting from similar markings and the divided dorsal fins, many internal characters are alike. The excretory system is suggestively similar in the two. In both forms the body cavity extends slightly posterior to the vent as two lateral pockets partially divided by the interhaemals beneath the base of the anal fin. *Auxis* alone of the investigated species has the pylorus opening into the stomach at an appreciable distance from the anterior end. It thus approaches the condition in the mackerel, where the pylorus opens near the mid-length of the stomach. *Auxis* is the only species in which the ventral cutaneous artery arises directly in the aorta. While this might appear to be irrelevant, it suggests a closer approach to the parent stock from which this group arose. As in the mackerel, the neural canal in all species of the Katsuwonidae is divided into two passages.

In an impartial study of relationships the above listing of facts can no more be ignored than the unique characters relating the Thunnidae with the Katsuwonidae. Were the complete evolutionary record available, such observations would serve to knit the pieces into an integrated whole. Lacking the complete picture, such facts are now contradictory. Their primary value is to warn against the acceptance of any false scheme of relationship. In the light of present knowledge, the writer believes that a valid, integrated scheme of relationships—one which will explain and reconcile the conflicting evidence—cannot be achieved, and

that any present attempt is premature and presumptive. Until such time as the attempt is warranted, it seems advisable to leave the classification in the status quo, or rather select the most logical of the existing alternatives and accept this as a temporary expedient.

Of such alternatives, the classification of Kishinouye accords best with the facts. The segregation of the tunas proper into a family Thunnidae, and the grouping of *Auxis*, *Euthynnus* and *Katsuwonus* into a second family, Katsuwonidae, is entirely in accord with these findings. Concerning the family Cybiidae, the writer has insufficient experience with this group to warrant an opinion. He accepts provisionally, the interpretations of Kishinouye.

For reasons discussed the writer cannot fully concur in the validity of combining the Katsuwonidae and the Thunnidae into a separate order. While this is a convenient and useful expedient, it may actually mask the true relationships rather than expose them. For this reason it would seem advisable either to eliminate the order, or to use it provisionally as an admittedly questionable but useful expedient. From an industrial and practical standpoint it is a convenience to group under one designation those species that support the tuna industry.

From this standpoint an acceptable popular definition of the term "tuna" is limited, by biological evidence, to two alternatives. The name "tuna" should either be restricted to any member of the family Thunnidae, or it can be expanded to embrace this family and any member of the family Katsuwonidae. Any other definition is arbitrary, and lacking in biological justification. It would seem preferable from purely academic considerations to restrict the term to members of the Thunnidae. However, since the term has for years been used loosely on this coast to include the skipjack (*Katsuwonus*) it will undoubtedly be more practical to expand the definition to include members of the family Katsuwonidae. Explicitly, this definition would restrict the term to Kishinouye's order Plecostei, embracing only those fish which possess

1. A cutaneous vascular system, and
2. A prootic pit in the skull.

All the fish thus included will fall unequivocally into two familial and several generic groups, which may be positively identified by the following abridged key.

Tunas: Those fish which possess both a cutaneous vascular system and a deep prootic pit in the skull. No exceptions. (Externally all members of this group can be identified by their fusiform shape and greatly streamlined body; all have two dorsal fins with the first dorsal inserted approximately level with the pectoral fin, and all have at least seven dorsal and six anal finlets. These external characters will include members of the family Cybiidae which do not belong with the tunas. The Cybiidae can generally be recognized and thus eliminated by the fact that the upper outline of the first dorsal fin is straight or even convex, whereas in all tunas it is concave.)[5]

Order: Plecostei (of doubtful validity)

[5] In all members of the Thunnidae and Katsuwonidae the tongue has two dorsally projecting lateral cartilaginous ridges. The bonito lacks these ridges. If they are consistently absent in all members of the Cybiidae, this character would be a valuable definitive one to segregate positively all members of Kishinouye's order Plecostei. The writer has not had the opportunity to investigate this.

A. Those tunas having a folded intestine, and the spleen showing, totally or in part, in ventral view. No exceptions. (Externally, members of this group can be readily identified by the completely scaled bodies which have no black bars or markings on either the back or belly.)

Family: Thunnidae

1. Liver, ventral surface, is marked extensively on all lobes with conspicuous radiating blood vessels. No exceptions. (Externally, not all species can be readily separated from other genera.)

Genus: *Thunnus*

2. No vascular markings on ventral surface of liver.[6] No exceptions. (Externally, this genus can generally but not always be identified by the pectoral fin which reaches to or beyond the insertion of the second dorsal fin, but not beyond the insertion of the anal fin.

Genus: *Neothunnus*

3. Fine peripheral markings on ventral surface of liver. These may disappear in stale specimens. Identification corroborated by the fact that spleen is partially concealed by a long fold of intestine, so that only anterior portion of spleen is exposed. (My observations are confined to one species, *P. mebachi*, which externally cannot always be readily separated from other genera.)

Genus: *Parathunnus*

B. Those tunas having a straight intestine, without a fold in it, and the spleen dorsolateral to the stomach so that it is entirely concealed in ventral view. No exceptions. (Externally all members of this group can be readily identified because they are devoid of scales posteriorly, beyond the corselet, and all have black bars or black markings either dorsally or on the belly.)

Family: Katsuwonidae

1. Dorsal and ventral branch of cutaneous artery approximately equally developed, with both contributing arterioles to vascular plexus in dark meat of lateral line. 41 vertebrae. No exceptions. (Externally this genus can be readily identified by lack of black markings above lateral line, and presence of longitudinal, oblique black stripes on silvery belly.)

Genus: *Katsuwonus*

2. Ventral branch of cutaneous artery short, dendritic, and contributing nothing to vascular plexus along mid-lateral line.

a. Dorsal cutaneous artery lies dorsal to corresponding cutaneous vein. No exceptions. 37 or 39 vertebrae. (Externally all members of this genus can be readily identified because the two dorsal fins are contiguous, and there is a series of oblique or longitudinal black markings above the lateral line.)

Genus: *Euthynnus*

b. Dorsal cutaneous artery lies ventral to corresponding cutaneous vein. No exceptions. 39 vertebrae. (Externally all members of this genus can be readily identified because the two dorsal fins are widely separated, as in the mackerel, and there is invariably a series of wavy black markings above the lateral line.)

Genus: *Auxis*

The above key is not designed for ready identification, nor is it designed to accord with taxonomic convention. It is intended to supply a rigid screen which will, primarily, sort out everything that does not comply with the two alternative definitions of the so-called tunas, and secondarily, differentiate the genera. This work is intended as a contribution to, rather than a monograph on, the group discussed. It is based essentially upon laboratory findings and not upon a critical review of the entire literature.

[6] The two species of this genus that I have examined, *N. macropterus* and *N. argentivittatus*, both have the heavy, conspicuous, circular connective tissue cord along the mid-dorsal wall of the body cavity, protruding into the air bladder. I cannot tell from Kishinouye's description whether or not this is present in *N. rarus*. If so, it becomes a positive generic character.

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